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EVALUATION OF WATER QUALITY IMPACTS ASSOCIATED WITH ASTARIS AND SIMPLOT PHOSPHATE ORE PROCESSING FACILITIES, POCATELLO, IDAHO

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IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY TECHNICAL SERVICES DIVISION

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EXECUTIVE SUMMARY

A study was undertaken at the request of the Pocatello Regional Office the primary purpose which was to evaluate the potential phosphorus and nitrogen loading contributions from groundwater emanating from beneath two ore processing facilities, as well as other local potential contaminant sources, to the lower Portneuf River. The primary objective was to provide information that may be used in the development of a TMDL for the lower Portneuf River.

Numerous data sources were utilized to evaluate orthophosphate trends over time and space, geochemical controls on contaminant transport, and loading of various sources in the study area to the lower Portneuf River. These data sources included ground water monitoring data form the Astaris and Simplot facilities, ground water quality data from the Idaho Department of Water Resources Statewide ground water monitoring network, ground water monitoring data from the Simplot wastewater land application site, water quality and stream discharge data from the Portneuf River collected by DEQ personnel, water quality data from the Batiste Spring channel collected by DEQ personnel, ground water quality data from monitoring wells at the City of Pocatello wastewater treatment plant and sludge treatment facility, and discharge effluent data for the City of Pocatello wastewater treatment plant.

INTRODUCTION

PROBLEM STATEMENT

The lower Portneuf River flows north-northwest from the City of Pocatello to its discharge point in American Falls Reservoir. The Idaho Department of Environmental Quality (IDEQ) is currently developing a Total Maximum Daily Load (TMDL) for the river. A TMDL allocates loading of contaminants from various sources to the river to ensure that the designated beneficial uses of the river, such as cold water biota, etc. are supported. The proposed TMDL target for total phosphorus in the lower Portneuf, which is currently out of attainment, is 0.075 mg/l.

As the river leaves the City of Pocatello its discharge relationship with the local ground water system changes from a losing condition to a gaining condition. This transition also coincides with a significant increase in phosphorus concentration and loading. Some of the most potentially significant sources of phosphorus to the river in this reach are two phosphate ore processing facilities, Astaris (formerly FMC Corporation) and J.R. Simplot.

PURPOSE AND OBJECTIVES

The Pocatello Regional Office (PRO) of IDEQ requested the Technical Services Division perform the following study. The primary purpose of the study is to evaluate the potential contribution from groundwater emanating from beneath the ore processing facilities, as well as other local potential contaminant sources, to phosphorus and nitrogen loading in the lower Portneuf River. The primary objective is to provide information that may be used in the development of a TMDL for the lower Portneuf River.

The tasks that have been completed to achieve this purpose and objective fall into three general categories; analysis of chemical trends, analysis of site geochemistry, and evaluation of contaminant loading. The specific tasks include the following:

- A background review of the hydrogeological assessments completed by FMC and Simplot, including associated monitoring data, well construction /lithological logs, groundwater flow models, and Portneuf River data including flow volumes and associated analytical data.
- Preparation of various maps, figures and tables for presentation of data.
- Statistical analysis of groundwater quality data along one or more flow paths, from upgradient to downgradient locations, using the existing well data.
- Geostatistical analyses of select contaminant data (e.g. orthophosphate and nitrate) through time to determine correlation length of the collected data.
- Determine if sufficient data are available, and if so, do contaminant trend analysis for selected monitoring well locations.
- Evaluate groundwater geochemistry at 1) locations along several flow paths from source areas to discharge points, 2) between shallow and deep aquifers to determine geochemical controls on contaminant fate and transport.

- Based on all the work described above, summarize results as to the potential impacts on local groundwater and the Portneuf River, and develop technical recommendations regarding identified data gaps and additional monitoring/remediation that may be needed related to TMDL development and implementation.

DATA SOURCES AND METHODOLOGY

Numerous sources of information and data were utilized for the purposes of this evaluation. These data sources include:

- Database of historical monitoring data results for the study area associated with the Eastern Michaud Flats Superfund investigations. The database was generated by Bechtel Environmental, Inc.
- Database of historical monitoring data associated with RCRA monitoring on the Astaris facility.
- Database of monitoring well locations and historical monitoring data for selected constituents from the 300 to 500 series groundwater monitoring wells. The database was supplied by the J.R. Simplot Co.
- Portneuf River transect data and Batiste Springs channel monitoring data collected by Idaho Department of Environmental Quality, Pocatello Regional Office.
- City of Pocatello wastewater treatment plant discharge data and sludge pond monitoring well data.
- Statewide GW monitoring well network data from Idaho Department of Water Resources.

The reports reviewed in preparation of this report are listed in the References section. The methodology used to complete the project tasks is described in detail in the sections that follow.

STUDY AREA DESCRIPTION

The study area, illustrated in figure 1, is located immediately northwest of the City of Pocatello and east and west of the lower Portneuf River in the areas known as Michaud Flats and the Fort Hall Bottoms. The Bannock Range rises directly west of the Astaris and Simplot facilities.

DESCRIPTION OF FACILITIES AND SITE HISTORY

The Astaris and Simplot facilities have been processing phosphate ore since the 1940's. The products, processes, and waste products of the two facilities are very different. The Astaris plant utilizes an arc furnace method to produce elemental phosphorus while the Simplot facility to the south uses sulfuric acid to produce phosphoric acid. Waste products associated with Astaris are kiln slag and liquids, formerly deposited in numerous unlined ponds, resulting from calcining and other processes. Simplot primarily produces phosphogypsum as a waste product, initially placed as a slurry in ponds and then redeposited in extensive "stacks". Phosphogypsum, as its name implies, is primarily gypsum along with numerous impurities resulting from the ore processing. Phosphorus is found in all of these potential source areas, primarily in the orthophosphate form. Other contaminants associated with these sources include arsenic, selenium, zinc, cadmium, vanadium, and fluoride, as well as major ions such as sodium, potassium, chloride, nitrate, ammonia, and sulfate.

As a result of contamination releases from the source areas described above both facilities were included in the Eastern Michaud Flats (EMF) Superfund site. The site was listed on the National Priorities List (NPL) in August 1990, and FMC and Simplot agreed to conduct a Remedial Investigation/Feasibility Study (RI/FS) for the site, starting in 1992. As a result of these RI/FS activities numerous wells were installed. The location of these wells is shown in figure 2. A Record of Decision (ROD) was issued in 1998.

The original remedy, as described in the ROD, addressed two Operable Units (OUs), the FMC and Simplot Plants. The OUs included Off-Plant Areas respective to both facilities. The major components of the selected remedy are described below.

The remedy for the FMC OU included: capping the old Phossy Waste Ponds and Calciner Solids Storage area and lining the Railroad Swale to reduce or eliminate infiltration of rainwater to groundwater and prevent exposure to contaminants; monitoring groundwater and implementing Institutional Controls (ICs) that will prevent the use of contaminated groundwater for drinking purposes under current and future ownership. Groundwater monitoring and ICs were to continue until site contaminants of concern (COCs) in groundwater declined to below Maximum Contaminant Levels (MCLs) or risk-based concentrations (RBCs) for those contaminants. Other facets of the remedy included additional ICs to prevent potential future residential use and control potential worker exposures under future ownership, and implementation of a contingent ground water extraction/treatment system if contaminated groundwater was found to migrate beyond company owned property and into adjoining springs or the Portneuf River. Containment of contamination was expected to be achieved by hydrodynamic controls provided by low level pumping.

Extracted groundwater would be treated and recycled within the plant to replace unaffected groundwater that would have been extracted and used in plant operations.

The remedy for the Simplot OU included: implementation of a groundwater extraction system to contain contaminants associated with the phosphogypsum stack and operation and maintenance of that system, implementation of ICs to prevent potential future residential use of the Simplot property and control potential worker exposures under current and future ownership, excavation of contaminated soils from the dewatering pit and east overflow pond, and monitoring of groundwater and implementation of ICs to prevent the use of contaminated groundwater for drinking purposes under current and future ownership. Groundwater monitoring and enforceable controls were planned to continue until site contaminants of concern in ground water declined to below MCLs or RBCs for those contaminants.

The remedy for the Off-Plant Area (actions common to both Simplot and FMC Operable Units) included: implementation of ICs and monitoring in the Off-Plant area to restrict property use due to potential exposure to radionuclides in soils and inform future property owners of the potential risks associated with consumption of homegrown fruits and vegetables, and monitoring of flouride levels around the site in order to determine the levels of flouride present and to evaluate the potential risk to ecological receptors.

At Astaris, since the signing of the ROD, groundwater monitoring has continued to the present time as part of RCRA groundwater monitoring requirements involving nine waste management units.

REGIONAL HYDROGEOLOGY

The Portneuf River from north of Interstate 86 (I-86) to American Falls Reservoir is a gaining reach and serves as a discharge area for aquifers on both the east and west sides of the river. To the east, ground water in the Michaud Gravel moves out of the canyon of the Portneuf River at Pocatello and flows west to discharge to the river. On the west, regional ground water flow moves radially outward to the north, west and east from a broad area between I-86 and American Falls Reservoir. Ground water on the eastern part of this area discharges to the Portneuf River.

The ground water flux to the river from the east is probably large compared to flux to the river from the west because the eastern drainage area is large. Transmissivities on the east side of the river are generally larger than on the west. On the west, regional ground water flow is generally to the north, toward American Falls reservoir, with a small component of flow to the river (figure __).

LOCAL HYDROGEOLOGY

Michaud Flats, including the Astaris-Simplot complex, is underlain by the following units, youngest to oldest and shallow to deep:

Quaternary loess or silt, and gravels (surface cover) – underlies the facilities and surrounding area, mostly disturbed due to past construction activities and presence of structures, ponds (some closed), roads, and other site activities. Much of this layer constitutes the vadose (unsaturated) zone.

Upper gravel aquifer zone – includes the Michaud Gravel and Aberdeen Terrace deposits, the latter essentially reworked Michaud Gravel. The Michaud Gravel can include boulders up to four feet in diameter.

American Falls Lake Beds (AFLB) – the regional aquitard, which locally appears to pinch out near the Portneuf River. Most often noted on logs as silty clay and clay.

AFLB Fluviatile Facies –Sunbeam Formation and underlying basalt – comprises a thick, high transmissivity reservoir composed predominantly of coarse gravels, and fractured and vesicular basalt flows.

Where the AFLB appears to pinch out or disappear near the Portneuf River, the result is a relatively thick and unconfined reservoir, especially in the vicinity of Batiste Springs. The "pinch out" may be a result of erosion of the AFLB by the Bonneville flood, rather than a true stratigraphic change (or a combination of both). Groundwater flowing into Batiste Springs then reflects both the groundwater chemistry and contaminant loading from both the shallow (Michaud Gravels) and deep (section underlying the AFLB) aquifers.

An examination of the Simplot and FMC monitoring wells verifies that there appears to be predominantly gravels, silty and sandy gravels, and gravelly sands in those wells nearest the Portneuf River. South and southwest of the river and within the facility boundaries, there is a marked increase in silt, clay and silty clay at depth, in zones both above the AFLB (eolian and alluvial deposits) and below (alluvial and lacustrine deposits).

Groundwater flow in both the shallow aquifer and the deep aquifer beneath the facilities appears to exhibit a north or north-northwest component of flow in the southern part of the site indicative of flow off the Bannock Range bordering the site on the south. However, the predominant flow across the site in both aquifers is to the northeast, towards the Portneuf River. This flow direction was demonstrated in both earlier work and more recent work at the site (Bechtel,1994; Astaris Idaho LLC, 2001.), Figure 4 shows potentiometric contours on the shallow water table for the area around the Astaris/Simplot facilities (from Bechtel Environmental, August 1994, figure 3b).
In the western part of the Astaris area the potentiometric surface has a uniform slope toward the river. On the east side of the area a trough concentrates ground water toward the Batiste Spring and Swanson Road Spring discharge area.

The trough in the potentiometric surface is a reflection of a large transmissivity zone in the Michaud Gravel, deposited during the Bonneville Flood event. A zone with boulders ranging from three to four feet in size extends to the west along I-86, and coincides with the trough in the shallow water table (figure 5).

Ground water moving into this trough from the south is impacted from activities at the two facilities, while ground water moving into the trough from the north reflects regional ground water quality. As will be shown later, distinct water quality differences occur within a short distance perpendicular to the axis of this trough.

TREND ANALYSIS

TREND PLOTS

Time series dissolved groundwater orthophosphate and nitrate concentration data from selected wells across the two facilities were plotted to visually illustrate trends. Data were segregated by facility (Astaris and Simplot) and aquifer (shallow and deep). Plots of these data are presented in figures 6 through 13.

Time series trends for nitrate are shown in figures 6 through 9 (nitrate concentrations in figures 8 and 9 are plotted on a logarithmic scale). Several observations can be made. Nitrate concentrations for the wells selected show a greater range of concentrations in the shallow aquifer than in the deep aquifer. The range of concentrations is greater in the shallow aquifer under the Simplot facility (1 to several hundred mg/l) compared to the Astaris facility (1 to about 50 mg/l). Nitrate impacts to the deep aquifer have occurred under both facilities with one well under the Simplot facility (315) exceeding the Idaho groundwater standard of 10 mg/l. Much of the data is grouped in what could be considered background concentrations for the respective aquifers. Deep aquifer nitrate background concentrations appear to be approximately 0.5 to 1 mg/l while shallow aquifer concentrations are more variable and somewhat higher at 2 to 4 mg/l.

For the shallow aquifer, wells at both facilities where concentrations are elevated above the background appear to exhibit increasing concentration trends over time. This is illustrated for wells 313, 316, 320, 325, and 331 at the Simplot facility (figure 8) and wells 122, 134, and 111 at the Astaris facility (figure 9). For the Astaris wells a pattern of decreasing trend until around 1996-1998 followed by increasing concentrations to the present exists.

For the deep aquifer, with some exceptions, concentrations in the deep aquifer are generally decreasing or remain stable. Exceptions include wells 315 and 317 at Simplot and wells 107 and 117 at Astaris.

Time series trends for orthophosphate are shown in figures 10 through 13. Note that the scale for orthophosphate concentrations is logarithmic. Background concentrations in both the deep and shallow aquifer are generally below 0.1 mg/l and typically in the 0.02 to 0.04 mg/l range. Most shallow wells under the Simplot facility exceed this background value. For the Astaris facility the orthophosphate concentration ranges for the wells selected are, as with nitrate, generally greater in the shallow aquifer (hundreds of mg/l) than in the deep (around 1 mg/l. This is not the case at the Simplot facility where the range in the deep aquifer wells below the facility are approximately equal to that seen in the shallow aquifer.

For the shallow aquifer trends in concentrations at the Simplot facility appear to be generally increasing over time. This trend appears to occur regardless of concentration.

For the deep aquifer orthophosphate concentrations at Astaris are generally decreasing while they appear to be increasing under the Simplot facility.

GEOSTATISTICAL ANALYSIS

One purpose of collecting numerous measurements of contaminant concentrations is to model the spatial variability of the contaminants for the area of interest. Ideally, we would measure the geochemical parameters directly at each point in the entire aquifer, but this is neither cost effective or plausible. Instead, we must use the limited information we can gather, and then conduct geostatistical surveys of that information so that we can infer the relationships for the rest of the aquifer. A brief synopsis of certain aspects of geostatistics is given below. Those interested in a more specialized description of the different aspects of geostatistics should refer to various texts on the subject (e.g., Isaaks and Srivastava, 1989; Deutsch and Journel, 1998).

In geostatistics, the spatial variability of the investigated parameter can be described empirically by using semivariograms, which are equal to half the average squared difference between paired data values. The variogram gives a measure of the correlation between pairs of data points based on the distance separating the data points. Variograms are characterized such that further separation does not cause the variogram value to change. The range occurs when the variogram reaches a plateau, or sill, which typically is quantified by the variance of the data set. At distances beyond the range, measured values are statistically independent. The nugget is the variogram value at zero separation distance and accounts for the sampling error and short scale variability (Isaaks and Srivastava, 1989).

Variogram analysis was conducted for nitrate concentrations (mg/L) for the summers and winters of 1991, 1993, and 1994, and for orthophosphorous (P as PO_4) concentrations (mg/L) for the summers of 1992 and 1993 and for the winters of 1990, 1992, and 1993. Table1summarizes the nugget, sill, range, and model used for each of these analyses.

Evaluating duplicate data approximated nugget values. The total variance of the data set gave an approximation for the sill values. Since orthophosphorous showed a larger range in the data, the variance was much larger as well. At the scale given, the low nuggets used for the orthophosphorous models are insignificant compared to the total sill.
The range was modeled as a best fit for the given data set. The model chosen depends on how the data values are correlated, though the spherical model is usually a good model to start with (Buxton and Pate, 2001).

For both nitrate and orthophosphorous, the average range is about 600 meters regardless of the year or season tested. From a statistical point of view, this means that data collected at one point in space is correlated to data collected within 600 meters of that point. Drawing 600-meter radius circles from various wells at the site causes the entire area to be covered. This implies that, from a statistical point of view, no further wells need to be drilled for testing purposes to gain information about the spatial variability of nitrate or orthophosphate. Other reasons, such as identified data gaps for hydrogeological characterization, plume distribution, hotspot investigation, and contaminant flowpath evaluation may require the drilling of new wells.

STATISTICAL ANALYSIS OF TREND

The Mann-Kendall test for trend (Mann, 1945; Kendall, 1975) is a nonparametric test that is useful when the data set has missing values or when the data do not conform to a particular distribution. The Mann-Kendall test uses only the relative magnitudes of the data rather than their measured values. After performing the calculations for the Mann-Kendall statistic, hypothesis testing was performed. With each run, the null hypothesis, H_0, of no trend was tested against the alternative hypothesis, H_A, of either an upward or downward trend. Using statistical tables, the level of significance at which the null hypothesis can be rejected in favor of the alternative hypothesis was determined.

To better associate the trend analysis with the geochemical analysis, the statistical analysis was performed on selected shallow aquifer wells along approximate groundwater flow pathlines. Data were tested for trend for both nitrate (Table 2) and orthophosphorous (Table 3). For each flow path line, the table lists whether there is a positive, negative, or no trend, the level of significance for the trend, and the final measurement date and value used in the analysis.

Comparing trend along flow paths is made more difficult because the range of data varies between the wells. Some of the wells tested have as few as four sampling events (usually in 1992 and 1993). Others have as many as 39 sampling events (1990 to 2000). As more data becomes available on all the wells, the trends can be re-analyzed to determine whether cleanup methods are reducing the values of nitrate and orthophosphorous in the ground water.

The results of the statistical analysis of trends supports the visual evaluation discussed in the earlier section on Trend Plots. For orthophosphate concentrations nearly all the Simplot wells examined exhibited positive trends with time with a high level of significance while only four of twelve Astaris wells (110, 145, 156 and 159) show upward trends. For nitrate concentrations, the majority of both facilities exhibited positive upward trends. The level of significance of several of the positive trends in Simplot wells was low however (less than 60 percent).

GEOCHEMICAL ANALYSIS

METHODOLOGY

Since about 1990 both facilities have undertaken extensive site characterization and groundwater monitoring activities as part of the Superfund remedial investigation and feasibility study process. Over one hundred monitoring wells were installed and sampled, primarily during the period 1990-1994. Subsequent to the ROD being finalized in 1996 the Astaris facility has continued monitoring a select group of wells as part of RCRA monitoring. Since 1994 groundwater monitoring has also taken place on the Simplot facility.

This is the water quality database from which the data for the geochemical evaluation were selected. Data from the December 1993 sampling event was chosen because of the widespread coverage of wells sampled, the relatively extensive nature of the constituents analyzed, and the timing of the event with respect to the onset of remedial activities, such as pond closures, at the site. Where comparable data was available for selected wells, analyses from 1998 were also evaluated to assess the impact of remedial activities on changes in geochemical conditions.

During the period of most intensive monitoring a suite of approximately 40 field and laboratory parameters were measured at each well location. Despite the size of this database the adequacy of the data for the purposes of comparative geochemical analysis is limited by several factors. These include:

- Variability in analytical parameters measured over time. The ability to conduct sitewide historical comparison and facility to facility comparisons was constrained by the fact that in recent years only a limited set of parameters, many of which do not facilitate evaluation of geochemical conditions, were typically measured. For example, monitoring data obtained for Simplot facility wells for the period after December 1994 was limited in scope and did not contain critical parameters, such as pH, temperature, or redox potential necessary for a geochemical evaluation.

- Analysis of total concentrations rather than filtered, dissolved concentrations,

- Elevated detection limits for total concentrations for selected constituents such as aluminum and iron, and

- Uncertainty as to the reliability of difficult measurements such as oxidation-reduction potential.

The vast majority of analyses for trace elements and major ions was for total concentrations. At various times, but primarily early in the site characterization process, analyses for both dissolved and total concentrations were performed during the same sampling event. These data were examined for three elements; aluminum, manganese, and iron, to evaluate the impact of using total instead of dissolved concentrations.

For aluminum the range of the dissolved/total concentration ratio (in percent) for 42 samples was nearly zero to 130 percent with the 50th percentile value being 5 percent. For manganese this range for 49 samples was from nearly zero to over 100. The 50th percentile value was 66 percent. For iron the range was near zero to 250 percent with a 50th percentile value of 9 percent. Twenty of the 47 sampled dissolved iron concentrations were less than the typical detection limit for total iron concentration (0.0549 mg/l). The primary impact of these low ratios is introduction of inaccuracy into the calculation of saturation indices of minerals containing these compounds. The wrong minerals may be identified as controlling constituent solubilities.

Sitewide chemical distributions for groundwater parameters which may impact phosphorus and nitrogen transport (such as aluminum, fluoride, iron, manganese, pH, redox, and temperature) were examined along with published maps of groundwater flowpaths in the shallow aquifer. From these initial assessments the groundwater chemistry along two flowpaths, emanating from significant sources of phosphorus and nitrogen at the site and ending at the discharge area in the vicinity of Batiste Spring, were identified. One flowpath was selected from the Astaris site and one from the Simplot site. The flowpaths and wells selected along the flowpaths are shown in Figure 14. These flowpaths do not necessarily represent the locations with highest orthophosphate concentrations, are not the only ones which could have been chosen, but are considered representative of conditions at the facilities.

The Astaris flowpath selected is based on recent (6/2000) groundwater elevation data (Astaris Idaho LLC, 2001). A different flowpath could have been selected if earlier groundwater flow conditions were used. Changes in the potentiometric surface appear to have occurred, resulting in a more rapid turn in the flowlines to the east as shallow groundwater from the facilities mixes with regional ground water. These changes may be the result of reduced flux to groundwater associated with closure of the unlined ponds on the facility. Since the cessation of site characterization activities in 1994 sitewide groundwater flow measurements that document patterns of sitewide flow have not been available.

Finally, given the pattern and nature of contaminant sources across the two facilities it was difficult to identify flowpaths for which only a single source of contamination could be identified. Typically, additional contaminant sources occurred, sometimes introducing significant changes in geochemical conditions along a given flowpath (such as a dramatic change in ground water temperature).

Groundwater data from wells selected to represent background conditions in the shallow and deep aquifers were compared to wells in the selected flowpaths.

Groundwater data from the selected wells were evaluated using the geochemical speciation model MINTEQ, Version 4.0 (USEPA, 2000). While several geochemical models are available MINTEQ was chosen because of the completeness of its thermodynamic database with respect to the numerous calcium phosphate minerals which appear to significantly influence phosphorus solubility at the site.

It was assumed for the purposes of this analysis that, given the large inputs of phosphorus into the aquifer, precipitation-dissolution reactions of solid phases are the dominant controls on phosphate solubility.

Groundwater parameters utilized as input to MINTEQ included total aluminum, iron, and manganese; the cations calcium, magnesium, sodium, and potassium; the anions chloride, fluoride, nitrate, and sulfate; orthophosphate; the field parameters pH, temperature, and oxidation-reduction potential; and ammonia.

SITEWIDE CONTAMINANT DISTRIBUTION

Figure 14 presents a map of the site with orthophosphate concentrations in groundwater from wells sampled during a March 1993 event. Orthophosphate concentrations in groundwater ranged from several hundred mg/l to non-detect levels. Figure 15 illustrates nitrate concentrations in wells in the shallow aquifer from a December 1993 sampling event. Concentrations range up to nearly 80 mg/l with significant concentrations present at both facilities.

RESULTS AND DISCUSSION

Tables 4 and 5 present a summary of the field parameters and chemical constituents of groundwater from wells located in the selected flowpaths that were used in the analysis. In these tables, wells are listed from left to right generally representing the downgradient flow direction from major source area to discharge point. At the far right side of each table are results are for Batiste Spring, the assumed discharge point, two wells representing background water quality of the shallow aquifers, and one well representing the deep aquifer system beneath the site.

The groundwater associated with the two facilities possess differences in their geochemical characteristics. Groundwater from wells along the Astaris flowpath is characterized by significantly lower concentrations of calcium, sulfate, and alkalinity, higher concentrations of potassium, chloride, and manganese, higher temperature and pH, lower oxidation-reduction potential, and higher orthophosphate levels than along the Simplot flowpath. These differences reflect the individual processes used to treat the phosphate ore at each plant. The impact of multiple sources of contamination along each flowpath can also be observed; for example, in the Astaris area the temperature rises dramatically at well 122, located in the vicinity of the kiln pit. In the Simplot area fluoride rises dramatically at well 327, located downgradient of the ore storage area and the East Overflow Pond.

Orthophosphate concentrations in the Astaris area, while initially higher, appear to be attenuated to a greater degree as groundwater travels toward the discharge area. This may largely reflect the greater opportunity for mixing and dilution with uncontaminated ground water of the Bannock Range aquifer to the north that is also flowing toward Batiste Spring and the river. Another interesting trend perhaps related to mixing is the dramatic decrease in concentrations of most constituents in the Simplot flowpath between wells 326 and 327. This decrease may reflect mixing with either the Portneuf aquifer system, the groundwater from the deeper system, or both.

The Piper diagram (Figure 16) also illustrates these differences in basic water chemistry. Background water chemistry is typified by water of the calcium-magnesium-bicarbonate water type, with the shallow groundwater upgradient of the facility having a greater influence of chloride or sulfate. Groundwater under Astaris shows a change to a sodium and potassium dominance while Simplot groundwater shows an increasing influence of both sodium and sulfate.

A final observation from the Piper diagram is that while both Astaris and Simplot waters plot distinct from the background wells, Simplot waters overlap to a large extent with waters that might be characterized as downgradient of both facilities, being located in the mixing zone area adjacent to the river. This may indicate greater contributions in terms of flux and consequently chemical loading to the river, from the Simplot facility than from Astaris.

The chemical analyses and field measurements of the groundwater solutions presented in Tables 4 and 5 were input into MINTEQ to calculate estimates of dominant species present and saturation indices for selected minerals.

The following observations can be made with respect to the speciation computations:

- Groundwater from background wells possessed high percentages of free ions such as Ca+2, F-, Fe+2, SO4-2, etc. Groundwater within the facility plumes had reduced percentages of these species with the difference often made up by neutral solid solution species such as CaSO4, MgSO4, FeSO4, and MnSO4 or charged complexes such as MnHCO3+.
- Aluminum in groundwater from background wells and all Astaris wells was typically present as Al(OH)4- or Al(OH)2+ while throughout all of the Simplot groundwater it was present as aluminofluoride complexes such as AlF+2, AlF2+, or AlF3.
- Complexes with bicarbonate tended to occur more frequently in the Astaris area than in the Simplot area.
- While the relative percentages of H2PO4- and HPO4-2 vary along a flowpath predictably in response to changes in pH the total contribution from neutral solid solution species such as CaHPO4 and MgHPO4 remains about the same.

The observations noted above relating to iron, aluminum, and to a lesser extent, manganese should be viewed with caution given the large differences noted earlier between dissolved and total measured concentrations.

Presented in Tables 6 and 7 are summaries of the MINTEQ calculated saturation indices (SI) with respect to selected mineral phases. For the purposes of this discussion, solutions with SI values between -0.5 and 0.5 are considered in equilibrium with the specified mineral phase. SI values greater than 0.5 are considered oversaturated and values less than -0.5 are considered undersaturated.

Along the Astaris flowpath the groundwater appears to be generally in equilibrium with respect to calcite and undersaturated with respect to gypsum. If a measured Eh of +150 mV is used as a general guide as a cutoff between oxidizing and reducing conditions, the redox conditions found along this flowpath appear to be mildly reducing. The exception is the highly reduced source area associated with wells 156 and 159. This conclusion is supported by the elevated levels of manganese and ammonia throughout. As a result of these conditions groundwater was calculated to be oversaturated with respect to $MnHPO_4$ and generally close to equilibrium with rhodocrosite, a manganese mineral that may act to control manganese concentrations in solution. The groundwater from wells 156 and 159 were also estimated to be near equilibrium with vivianite, an iron phosphate mineral.

Groundwater was consistently oversaturated with respect to the aluminum oxide mineral phases, very likely an artifact of the high analytical detection limits and the measurement of total instead of dissolved concentrations. This condition may also apply to iron as well, there being no iron mineral phases identified which were in equilibrium with the groundwater, except as noted above for vivianite.

The precipitation-dissolution relationships and mineral phase equilibria for phosphate are extremely complex and will not be examined in detail here. Lindsay (1979) provides an excellent review of the subject. There are a suite of calcium phosphate minerals, varying in degrees of crystallinity and solubility, which may be present in calcareous aquifers of circumneutral pH, similar to conditions measured at this site, that may act to control phosphate solubility, albeit at relatively high concentrations. These minerals include CA5(PO4)3OH (hydroxylapatite or HAP), CA3(PO4)2 (BETA-TCP), CA4H(PO4)2:3H20 (OCP), CAHPO4 (DCP) , and CAHPO4:2H20 (DCPD). The order of minerals presented above represents a series with respect to solubility and stability with the least soluble and most stable of these minerals being HAP and the most soluble and least stable being DCPD.

In the Astaris flowpath it appears that in the source area the groundwater is saturated with respect to all of these minerals except DCPD but as groundwater travels downgradient the equilibrium shifts to DCP then to BETA-TCP. Toward the downgradient end (well 146), where the groundwater has been mixed to a significant degree, the solution is undersaturated with all these minerals except for HAP, which remains oversaturated but progressively less so along the flowpath. This oversaturated condition for HAP resembles that seen at the discharge point as well as in upgradient, background wells. The type of transition observed, from more soluble to less soluble mineral forms with time or in this case groundwater travel along a flowpath, is also commonly observed in studies of phosphate fertilizer fate and availability in agricultural soils. The consistent excess saturation of HAP may represent a lack of true equilibrium of the mineral with respect to the groundwater solution. That is, the kinetics of HAP formation compared to groundwater flow rates, may be slow. The form of the mineral present in the aquifer, in terms of its purity and degree of crystallinity, may also not match that used to generate the K values used in the MINTEQ database and may have higher solubility.

In the Simplot flowpath the groundwater in the source area is similarly in equilibrium with calcite but also with gypsum. The solubility and presence of gypsum will act to reduce the activity of the calcium ion in solution and potentially increase the solubility of the calcium phosphate minerals with respect to phosphate.

Toward the downgradient vicinity of well 327 gypsum becomes undersaturated with respect to groundwater. In this same area increased levels of fluoride in solution and equilibrium conditions with fluorite, which can control fluoride concentrations in solution, indicate the potential for fluorapatite to precipitate and control phosphate in solution. In general the areas across the site where fluoride concentrations are high enough for this to occur are limited.

With respect to the calcium phosphate mineral phases the trend seen along the Simplot flowpath differs. Here DCPD, DCP, and BETA-TCP are all in equilibrium throughout the upper portions of the area. For the pH levels measured in these wells (6.3) it is not uncommon for these minerals to coexist. It is not until well 327 that the groundwater, as in the Astaris flowpath, becomes undersaturated with these minerals, though to a smaller degree. Since the pH in well 327 is very similar to that seen in the upgradient wells some other factor is controlling the mineral phases at this location. The same trends for HAP, as in the Astaris flowpath, are observed here. As with the relationships observed in the Piper Diagram, the saturation indices for various minerals at 327 and 503 are more similar to those seen at Batiste Spring than for similarly located downgradient wells on Astaris property such as well 146 and 122. This again suggests that groundwater and dissolved contaminants derived from Simplot operations provide a larger portion of the water seen at Batiste Spring than does Astraris operations, at least with respect to phosphate.

It has been observed for the calcium phosphate minerals discussed here that phosphate solubility decreases dramatically with increasing pH until the area of pH 7-8 when solubility begins to increase again. This is illustrated in Figure 12.8 of Lindsay (1979). Figures 17 and 18 present graphs of calcium activity and pH versus saturation indices for the phosphate minerals for Simplot and Astaris groundwater. These plots attempt to capture the effect of two major factors responsible for phosphate mineral solubility. For Astaris, saturation indices for all minerals appear to decrease in a predictable linear manner with increasing pH and/or calcium ion activity whereas for Simplot the same relationship is not present. Other factors may be controlling phosphate solubility at Simplot. The persistence of lower pH in the Simplot area, resulting in higher solubility of the calcium phosphate minerals may be responsible for the elevated phosphate concentrations observed.

SUMMARY AND CONCLUSIONS

Concentrations of orthophosphate at the primary groundwater discharge point at Batiste Springs have remained elevated as of December 2000, despite the closure of most unlined ponds on both facilities. Phosphate concentrations in most Astaris wells have declined since 1993 and at downgradient locations are lower than that observed at Batiste Spring. As described in more detail in the Trend Analysis section of this report Simplot area phosphate concentrations have generally been increasing since 1994. The concentrations of phosphate in groundwater under both Astaris and Simplot, even in most downgradient locations, still greatly exceeds the designated TMDL total phosphorus concentration in the Portneuf River.

With an estimate of the actual loading from these facilities to the river as well as their relative contribution an acceptable target concentration in groundwater could be developed. Depending on what the groundwater target concentration was, it is unclear as to whether the typical mineral phase geochemical controls on phosphate concentrations, as affected by pH, calcium activity, and other cations and anions could attain that target concentration without active remedial measures to modify subsurface geochemical conditions.

CONTAMINANT LOADING ANALYSIS

AREAWIDE GROUNDWATER QUALITY

Water quality data from 13 Statewide monitoring wells can be used to characterize area wide ground water quality (Figure 19).

Table 8 lists nitrate-N and total phosphorous concentrations from 13 wells in the East Michaud Flats vicinity. (Only total phosphorous concentrations are available from Statewide wells.) The wells were sampled at various intervals from 1991 through 1999, the most recent year that data are available. For Statewide wells on the east side of the Portneuf River, average nitrate-n concentrations range from 1.1 to 5.4 mg/L. For Statewide wells on the west side of the Portneuf River, average nitrate-N concentrations range from 2.6 to 5.6 mg/L. Average total phosphorous concentrations range from 0.01 mg/L to 0.06 mg/L for east side wells and 0.02 to 0.055 mg/L for west side wells.

BATISTE SPRING CHANNEL DATA

Water that discharges from Batiste Spring flows into a channel which runs parallel to the Portneuf River for a distance of approximately 1 mile. At the lower end of the channel, part or all of the spring flow is diverted through the Batiste Spring Trout Farm. After flowing through the trout farm facility, the water discharges to the Portneuf River, just upstream of transect location T-7.

During the period May 4, 1999 through December 7, 2000 five locations along the Batiste Spring Channel were sampled monthly for chloride, sulfate, bicarbonate alkalinity, total dissolved solids, ammonia, Total Kjeldahl Nitrogen, nitrite plus nitrate as N (NO2+NO3-N), total nitrogen, total phosphorus and orthophosphate, total suspended solids, and turbidity. These sample data are included in Table 9. The five sample locations, shown on Figure 20, include the spring house, loading dock (Meadow Gold/Rowlands Dairy), culvert, spillway (above Batiste Springs Trout Farm), and the Batiste Springs Trout Farm discharge (hatchery effluent).

Figure 21 shows total nitrogen, total phosphorous, CaCO3 alkalinity, total dissolved solids, chloride and sulfate trends at the five sample locations for November 11, 2000. Similar trends exist for other sample dates throughout the sampling period.

Flow in the Batiste Spring channel is believed to increase downstream of the initial discharge point at the springhouse. A discharge of 5.7 cubic feet per second (ft^3/sec) was reported at the spring (Perry and others, 1990) and a discharge of 12 on June 22, 1994 was reported where the channel discharges to the river (Bechtel Environmental, 1994), for a gain of about 6 ft^3/sec. Although the measurements were taken at different times, they indicate that the channel receives additional water from ground water discharge between the spring and Batiste Springs Trout Farm.

PORTNEUF RIVER TRANSECT DATA

During September 13 and 14, 2000, ten transects were sampled on the Portneuf River, from just upstream of the I-86 crossing (Transect 1 or T-1) to just below or downstream of Papoose Springs (T-10). Figure 20 shows the location of the transects. At each transect, discharge was measured and samples were collected for analysis of total ammonia, total nitrite/nitrate, total Kjeldahl nitrogen, dissolved orthophosphorous, and total phosphorous (table 9 and figure 22). These data were used to calculate contaminant loading at the transects. These calculated loading values are presented in table 10 and illustrated in figure 23. At transects T-6 through T-10 pH, conductivity, and temperature information were collected.

The stretch of river downstream of I-86, and downgradient (northeast) of Eastern Michaud Flats, has historically been known to be a gaining reach of river due to the numerous springs discharging along the banks and the bottom of the streambed. This streamflow gain is demonstrated in the transect data, which shows a flow of 77.91 cubic feet per second (ft^3/sec) at T-1, increasing to as much as 276 ft^3/sec at T-9 (figure 23).This is almost a four-fold increase in flow. Equally notable is the increase in contaminant concentrations through this stretch (figure 22), and consequent loading to the stream. For example, the loading to the stream at T-1 is 12 lbs/day and 18 lbs/day, for nitrogen and total phosphorous, respectively. At T-2, the flow and the select contaminants cited increase, to 107 ft^3/sec and 721 lbs/day and 747 lbs/day. The increase in flow and contaminant loading peak at T-9, where flow is 276 ft^3/sec and loading is 4448 lbs/day and 2146 lbs/day, again respectively.

These data alone appears to demonstrate a considerable increase in contaminant loading to the Portneuf River in the gaining reach adjacent to Eastern Michaud Flats. It is likely a portion of the gain, and, especially a portion of the increase in contaminant loading results from the influx of EMF groundwater. The following sections provide a basis for these assumptions.

POCATELLO WWTP LOADING

The City of Pocatello wastewater treatment plant discharges treated effluent to the Portneuf River at a point located between transects T-3 and T-4. This discharge is regulated under an EPA NPDES permit. Analytical parameters required in the permit include average daily flow, ammonia, Total Kjeldahl Nitrogen, total and ortho phosphorous, and nitrite plus nitrate as N (NO2+NO3-N). Data for the period January 2000 through March 2001, shown in Table 11, were evaluated for this project. Analytical data for the treated discharge are available for September 13 and 14, 2000, the days when the Portneuf River transect data were collected. These data are included in Table 9.

SIMPLOT WASTEWATER LAND APPLICATION SITE

Industrial wastewater from the Simplot Don Plant is land applied during the growing season to approximately 328 acres on the east side of the Portneuf River, in accordance with DEQ wastewater land application permit LA-000104-01. The acreage is divided between three fields, shown on figure 24. Wastewater applications are reported to be uniform at all three acreages. Three ground water monitoring wells around the Swanson acreage have been sampled have been sampled since 1992 for constituents including NO3-N and ortho-phosphorous; the Spanbauer and BAPCO/Carlsen acreages do not have ground water monitoring systems. Well 513 is an upgradient well, and wells 509 and 511 are downgradient wells (figure 24). Table 13 shows average NO3-N and ortho-phosphate concentrations at these wells. Average NO3-N concentrations are similar to NO3-N concentrations in statewide monitoring wells; average ortho-phosphorous concentrations are similar to statewide monitoring wells with the exception of well 509 (average orthophosphate concentration for 9 observations was 0.11 mg/L). However, at this well, one orthophosphate concentration of 0.8 mg/L was reported; if this value were excluded the average orthophosphate concentration at the well would be 0.038 mg/L. Based on these data, and assuming that the results are representative of ground water at the other two wastewater land application acreages, the wastewater land application sites do not contribute significant phosphorous loading to the Portneuf River.

FACILITY GROUNDWATER LOADING

Orthophosphate and NO3-N loading to the Portneuf River from the Astaris/Simplot area in the shallow aquifer were evaluated for the shallow aquifer system prior to mixing with the deep aquifer. The general steps in the evaluation were to first estimate the ground water flow volume from the area and then multiply this flow volume by NO3-N and orthophosphate concentrations to arrive at a mass load. These loads can be compared to data from the transect sampling conducted during September 2000.

The first step in the evaluation was to construct a series of ground water flow path lines on the June 1994 Bechtel potentiometric map for the shallow aquifer (Figure 25, adapted from Bechtel, 1996, figure 2.2.7). Next, the saturated thickness of the shallow aquifer within the resulting flow tubes was calculated by subtracting the elevation of the top of the American Falls Lake Bed from the appropriate water table elevation, in this case the 4384 foot water table contour. The cross sectional area of the shallow aquifer within each flow tube was then calculated by multiplying the saturated thickness by the lateral distance between adjacent flow path lines.

The ground water flow volume within each flow tube was then estimated using the Darcy equation:

$Q = KiA$, where

> Q = ground water flow volume (ft3/day)
> K = hydraulic conductivity of the shallow aquifer (ft/d) (from Bechtel Environmental, Inc., August 1994),
> i = hydraulic gradient (ft/ft), from potentiometric map, and
> A = cross sectional area of the aquifer (ft2).

For each flow tube, the most recent NO3-N and orthophosphate concentrations in the monitoring well closest to the 4384 foot contour line were used to represent ground water quality in that flow tube.

From north to south, representative flow tube wells included 502, 517, 331, 335S, 327 and 318. Finally, the ground water flow volume was multiplied by the orthophosphate and NO3-N concentration at each well to get a constituent load and the results were summed for a total load to the river. The evaluation results are listed in table 14.

Stream flow gains and contaminant loading between transects T-1 and T-2 can be compared with shallow aquifer discharge and loading information for adjacent flow tubes. Ground water discharge from flow tubes represented by wells 517, 331, 335S 327 and 318 is about 4.2 ft^3/sec, compared to the river gain of about 29 ft^3/sec between transects T-1 and T-2.

The difference of about 25 ft^3/sec in stream flow gain between T-1 and T-2 comes from a combination of ground water discharge from the aquifer east of the river and ground water discharge from the deep aquifer underlying the Astaris/Simplot facilities. Orthophosphate loading from the same shallow aquifer flow tubes is estimated to be about 562 lbs/day, compared with a total phosphorous load at transect T-2 of about 747 lbs/day. Thus, about 75 percent of the phosphorous load to the river at transect T-2 comes from the Astaris/Simplot area. Approximately 92 percent of the nitrogen load to the river at T-2 come from the Astaris/Simplot area (666 lbs/day from the shallow aquifer versus 721 lbs per day in the river).

Contaminant loading associated with the 25 ft^3/sec stream flow gain can be estimated using representative concentrations of orthophosphate and NO3-N from wells completed in the deep aquifer beneath the Astaris/Simplot area and from wells on the east side of the river. On the east side of the river an upper limit for orthophosphate in ground water is about 0.03 mg/L; the background NO3-N concentration is approximately 3.0 mg/L. In the deep aquifer on the west side of the river, orthophosphate concentrations vary with location. Deep well 519 had an orthophosphate concentration of 0.04 mg/L while deep well 317 had an orthophosphate concentration of 265 mg/L. Statewide wells north of the Astaris/Simplot site have orthophosphate and NO3-N concentrations of approximately 0.03 and 4.0 mg/L, respectively.

The orthophosphate load in a discharge of 25 ft^3/sec is approximately 0.5 lbs/day, using a concentration of 0.03 mg/L; the NO3-N load in the same discharge volume would range from about 54 to about 72 lbs/day using a concentrations of 3.0 to 4.0 mg/L.

DISCUSSION

The following points can be made from a review of discharge, water quality and loading calculations for Batiste Spring, Batiste Spring channel, the Portneuf River and shallow aquifer loading calculations:

Flow in the river, from both discrete spring sources and diffuse flow into the channel bottom, increased by about 186 ft^3/sec from transect T-1 through T-10 during the period September 13-14, 200 (from 78 ft^3/sec to 264 ft^3/sec, figure 22).

Batiste Spring and Swanson Road Spring contribute a combined flow estimated to be 15 to 20 ft^3/sec to the river, and the shallow aquifer under the Astaris/Simplot area contributes an estimated 4.3 ft^3/sec.

The river gains up to transect T-4 but loses flow to ground water at transects T-6 and T-7. This water apparently re-enters the river at transect T-8; below T-8 the stream flow is relatively constant through transect T-10.

The stream flow gain between transects T-1 and T-2 can be compared to discharge from the shallow aquifer to the river along the same reach; the shallow aquifer contributes about 15 percent of the increase in flow between these two transects (4.2 ft^3/sec versus 29 ft^3/sec). Discharge estimates from the deep aquifer were not possible due to limited information on aquifer properties.

Nitrate-N, total and orthophosphate concentrations in the river increase dramatically between transects T-1 and T-3. Downstream of T-3, NO3-N concentrations in the river are in the range of 2.6-2.7 mg/L, reflecting inflow of ground water with a similar NO3-N concentration. Phosphorous concentrations gradually decrease downstream of transect T-3, reflecting the inflow of ground water with low phosphorous concentrations, in the range of 0.03 to 0.04 mg/L. The interval where poor quality ground water enters the river occurs between transects T-1 and slightly north of Batiste Spring. Well 525, which is about 200 feet north of Batiste Spring, has measurably improved water quality compared to the spring.

The concentrating effect of the trough in the shallow water table results in significant water quality changes over short distances north or south of the axis of the trough. Ground water originating from areas north of the axis of the trough has water quality similar to ambient water quality shown in table 8.

Changes in water quality along the Batiste Spring channel confirm the above observations. Concentrations of parameters including chloride, sulfate, nitrate and phosphorous decrease by approximately one half between the springhouse and the loading dock, a distance of approximately 350 feet. Although decreases in phosphorous concentration could be attributed to aquatic effects, decreases in concentrations of conservative tracers such as chloride and nitrate are most likely due to dilution by good quality ambient ground water originating from the north of the FMC/Simplot facilities.

Loading calculations for the City of Pocatello wastewater treatment plant effluent show that this source of phosphorous load to the river is inconsequential compared to the total load in the river (table 11). During some periods nitrogen loading to the river from the wastewater treatment effluent may be a significant percentage of the nitrogen load in the river at T-4.

Loading calculations for the shallow aquifer discharging from the Astaris/Simplot area indicate that the site contributes about 75 percent of the measured phosphorous load in the river between transects T-1 and T-2 and about 90 percent of the nitrogen load to the river over the same reach. Phosphorous and nitrogen loads in the river continue to increase downstream of T-2, at transects T-3 and T-4. This additional load may be from intergravel flow contributions to the water column downstream of where ground water first flows into the river. As previously noted, phosphorous concentrations in ground water entering the river below transect T-2 are low, and the impact of this source to the river can be evaluated. Using a ground water phosphorous concentration of 0.04 mg/L and a stream flow gain of about 75 ft^3/sec between transects T-2 and T-4, the phosphorous load to the river from ground water would be about 16 lbs/day, compared to an phosphorous load about 2000 lbs/day based on stream flow and water quality data from the river. In a similar fashion, NO3-N loads to the river between transects T-2 and T-4 from ground water are estimated to be about 1200 lbs/day (3.0 mg/L NO3-N and 75 75 ft^3/sec river gain).

CONCLUSIONS

Conclusions of the data analysis conducted includes:

- Releases of phosphorus and nitrogen to the environment associated with operations of the Astaris and Simplot phosphate ore processing facilities have significantly impacted both the shallow and deep aquifer systems underlying these facilities.
- Concentrations of orthophosphate in the shallow aquifer associated with the Simplot facility are increasing with time. Wells with elevated concentrations of nitrate in the shallow aquifer at both facilities exhibit increasing trends. These trends in concentration over time are illustrated visually and supported by a non-parametric statistical analysis of trend.
- Geostatistical analysis of the spatial variability of orthophosphate and nitrate concentrations in the shallow aquifer beneath both facilities indicates a correlation length of approximately 600 meters indicating that, statistically, the current monitoring well coverage adequately captures the variability in orthophosphate and nitrate in the study area. New wells may be needed to better characterize the hydrogeology in specific locations.
- Geochemical evaluation of groundwater data at both facilities illustrates that differences in waste products produced by the two facilities, as a result of differences in process and operation, have resulted in differing geochemical conditions. These differing geochemical conditions have shown varying potential to attenuate orthophosphate in the groundwater system, with the Astaris facility being more successful than the Simplot facility.
- Nearly all shallow wells associated with both of these facilities exceed the TMDL target. Given the length of time since the implementation of remedial measures (1995) the ability of the groundwater system to naturally control orthophosphate concentrations to some designated target concentration without additional active remedial measures should be questioned.
- Discharge of phosphorus and nitrogen from these impacted aquifer systems to the Portneuf River represents a significant portion of the total load measured in the river.
- Downstream of the zone where phosphorous loads enter the river, phosphorous concentrations in the river gradually decrease in response to influx of ground water containing low phosphorous concentrations. Nitrogen loads in the river downstream of the facilities continue to increase in response to elevated nitrogen concentraions in ground water.
- The zone of contribution of poor quality water to the river from the Astaris and Simplot area is controlled by hydrogeological conditions. Available monitoring data indicate this zone extends about 1500 feet along the river; additional monitoring could define this zone more precisely.
- The river loses approximately 50 percent of its discharge to ground water between transects T-4 and T-6. Any contaminant load contained in the river also enters ground water along this reach of the river. The flow component reenters the river below Transect T-6, possibly as spring flow from the east side of the river. The impact to ground water along this reach is unknown.

- Evaluation of phosphorous loads from the Simplot wastewater land application area, the City of Pocatello wastewater treatment plant effluent and the City of Pocatello sludge lagoon facility all indicate these sources do not contribute significant phosphorous loads to the river.
- Likewise, an evaluation of the phosphorous load in ground water discharging to the river below the Astaris and Simplot facilities indicates that this is not a significant source of phosphorous to the river.
- The TMDL for the Portneuf River has been established at 0.075 mg/L total phosphorus; concentrations at most points in the shallow aquifer under both facilities exceed this value.

RECOMMENDATIONS

Based on the results and conclusions of the analysis detailed earlier, the following recommendations are presented.

- A current sitewide map of groundwater elevations in both the shallow and deep aquifers is needed to document the nature of changes in the flow field since the implementation of remedial measures. Sitewide groundwater elevation measurements should be renewed.

- Monitoring for groundwater parameters which may potentially control phosphorus and nitrogen fate and transport should continue and, if discontinued should be renewed. These parameters include pH, temperature, oxidation-reduction potential, dissolved oxygen, major ions such, and perhaps on a limited basis speciation of selected parameters such as iron and aluminum.

- Resampling of the Portneuf River transects to confirm the gain and loss relationships between transects T-4 and T-7, measured during the September 2000 monitoring event, should be completed. A spring inventory along the east side of the river in this reach should also be conducted.

- A systematic monitoring program to better characterize the interaction of the groundwater system with the Batiste Spring channel and the river, with respect to water quality and water balance should be implemented.

- Given the finding that the estimated large contribution to phosphorus and nitrogen loading to the river from the two facilities occurs over a relatively short reach of the river additional efforts to better characterize the spatial location, amount, and mode of this discharge should be initiated. These characterization efforts would facilitate the implementation of more focussed remedial measures. These characterization activities could include additional, more closely spaced river transect locations, measurement of additional parameters such as temperature, and installation of piezometer nests in the river bed to document rates of groundwater seepage and water quality.

- Based on the continued elevated concentrations of orthophosphate and nitrate at Batiste Spring, increasing concentrations trends for these constituents in the shallow ground water system, and the significant contribution of these facilities to orthophosphate and nitrate in the Portneuf River, a reevaluation of the effectiveness of remedial measures that have been undertaken and/or proposed by the facilities should be initiated.

REFERENCES

Astaris Idaho LLC. 2001. RCRA Interim Status 2000 Groundwater Monitoring Assessment. February 2001. Pocatello, Idaho.

Bechtel Environmental, Inc. 1994, Ground water flow modeling report; prepared for FMC Corporation and J.R. Simplot Company, 45 pages, 3 appendices. August.

Bechtel Environmental, Inc. 1996. Remedial Investigation Report for the Eastern Michaud Flats Site. Prepared for FMC Corporation and J.R. Simplot Company. August.

Buxton, B. and A. Pate. 2001. *Geostatistics and the Data Quality Objectives Process for Environmental Remediation Decision Making.* National Ground Water Association Short Course.

Cascade Earth Sciences, May 1998, Process Water Management Plan, J.R. Simplot

Company Minerals and Chemicals Group, Pocatello Idaho; prepared by Cascade Earth Sciences.

Deutsch, C.V. and A.G. Journel. 1998. GSLIB: Geostatistical Software Library and User's Guide. 2nd edition. Oxford University Press. New York. 369 pages.

FMC Corporation. 1996. Feasibility Study Report. Sections 1 through 6. FMC Subarea. June 1996.

Isaaks, E.H. and R.M. Srivastava. 1989. An Introduction to Applied Geostatistics. Oxford University Press. New York. 561 pages.

Jacobson, N.D., 1984, Hydrogeology of Eastern Michaud Flats, Fort Hall Indian Reservation, Idaho: U.S. Geological Survey Water-Resources Investigations Report 84-4201, 31 p.

Jacobson, N.D., 1982, Ground-water conditions in the eastern part of Michaud Flats, Fort Hall Indian Reservation, Idaho: U.S. Geological Survey Open-File Report 82-570, 35 p.

Jacobson, N. D., 1989, Water-quality data for selected sites on Michaud Flats, Fort Hall Indian Reservation, Idaho, December 1982 to July 1987; U.S. Geological Survey Open-file Report 89-71, 26 p.

Kendall, M.G. 1975. Rank Correlation Methods. 4th Edition. Charles Griffon. London.

Lindsay, Willard L. 1979. Chemical Equilibria In Soils. John Wiley and Sons. New York.

Mann, H.B. 1945. Nonparametric tests against trend. Econometrica. v. 13. p. 245-259.

Mundorf, J. M., 1967, Ground water in the vicinity of American Falls Reservoir, Idaho: U. S. Geological Survey Water Supply Paper 1846, 58 p.

Perry, J. A., William H Clark and Orma J. smith Museum of Natural History, 1990, Groundwater classification through spring chemistry: the lower Portneuf River, southeastern Idaho; Journal of the Idaho Academy of Science, v. 26, no. 1/2, p. 55-71.

Trimble, Donald E., 1976, Geology of the Michaud and Pocatello Quadrangles, Bannock and Power Counties, Idaho: U. S. Geological Survey Bulletin 1400, 88 p.

USEPA. 2000. MINTEQA2. A Geochemical Assessment Model for Environmental Systems. Version 4.0. United States Environmental Protection Agency.

West, S. W., and Kilburn, Chabot, 1976, Ground Water for irrigation in part of the Fort Hall Indian Reservation, Idaho: U. S. Geological Survey Water Supply Paper 1576-D, 33 p.

Young, H. W., 1984, Water-table contours, direction of ground-water movement, and measurements of inflow to American Falls Reservoir, southeastern Idaho, April 1984: U.S. Geological Survey Water-Investigations Report 84-4269, 1 sheet.

Tables

Table 1. Summary of variogram analysis for nitrate and orthophosphorous

Contaminant	Time Frame	Nugget $[(mg/l)^2]$	Sill $[(mg/l)^2]$	Range (m)	Model
Nitrate	Summer 1991	28	92	1000	Spherical
Nitrate	Winter 1991	14	36	700	Spherical
Nitrate	Summer 1993	10	28	550	Spherical
Nitrate	Winter 1993	30	50	600	Spherical
Nitrate	Summer 1994	12	26	600	Spherical
Nitrate	Winter 1994	48	33	550	Spherical
orthophosporous	Winter 1990	0 5	825 820	840 475	Spherical Gaussian
orthophosporous	Summer 1992	0	2500	600	Spherical
orthophosporous	Winter 1992	0	4800	500	Spherical
orthophosporous	Summer 1993	0	25	300	Spherical
orthophosporous	Winter 1993	10	4000	625	Spherical

Table 2. Trend Analysis for time series nitrate data from selected wells.

Label	Flowpath Wells					
Well		156	159	134	122	146
Trend		Positive	Positive	Positive	Positive	Negative
Significance (%)		100	99	99.8	97	99.8
Last Value (mg/l)		0.2	0.4	16.2	28	5.5
Date of Last		Aug. '00	May '00	May '00	Aug. '00	May '00
Well		136	312	331	TW-12S	Batiste
Trend		Negative	Positive	Positive	Zero	Positive
Significance (%)		87	28	72	100	100
Last Value (mg/l)		2.3	4.26	31.8	6.9	8.0
Date of Last		May '00	Mar. '98	Mar. '98	Nov. '00	Nov. '96
Well	306	316	326	327	503	Batiste
Trend	Negative	Positive	Positive	Positive	Positive	Positive
Significance (%)	94	100	44	78	94	100
Last Value (mg/l)	1.42	25.1	14.7	3.14	5.26	8.0
Date of Last	Dec. '94	Mar. '98	Mar. '98	Mar. '98	Mar. '98	Nov. '96
Well				145	110	517
Trend				Zero	Positive	Negative
Significance (%)				89	85	64
Last Value (mg/l)				3.97	3.1	9.73
Date of Last				Dec. '93	May '00	Mar. '98
Well			134	TW-5S	111	TW-9S
Trend			Positive	Positive	Positive	Negative
Significance (%)			99.8	80	92	78
Last Value (mg/l)			16.2	21.4	14.7	3.91
Date of Last			May '00	Dec. '93	May '00	Dec. '94
Well				323	325	TW-12S
Trend				Positive	Positive	Zero
Significance (%)				100	52	100
Last Value (mg/l)				3.90	180[1]	6.9
Date of Last				Mar. '98	Mar. '98	Nov. '00
Well				323	325	320
Trend				Positive	Positive	Positive
Significance (%)				100	52	45
Last Value (mg/l)				3.90	180	194
Date of Last				Mar. '98	Mar. '98	Mar. '98

[1] From Dec. 1992 to Dec. 1995 nitrate in Well 325 fluctuated from about 20 mg/L to about 45 mg/L. There was no monitoring in 1996. Then, in March 1997 the nitrate value was 166 mg/L. The March 1998 value was 180 mg/L. No further nitrate monitoring was recorded.

Table 3. Trend Analysis for time series orthophosphate data from selected wells.

Label	Flowpath Wells					
Well Trend Significance (%) Last Value (mg/l) Date of Last		156 Negative 54 389 Mar. '00	159 Positive 100 19.2 May '00	134 Negative 99.6 20.2 May '00	122 Negative 94 5.9 Mar. '00	146 Zero 95 0.15 May '00
Well Trend Significance (%) Last Value (mg/l) Date of Last		136 Negative 90 85.2 May '00	312 Positive 91 36.7 Mar. '00	331 Positive 99.3 28.5 Mar. '00	TW-12S Positive 46 59.6 Dec. '94	Batiste Positive 99.8 12.6 Mar. '00
Well Trend Significance (%) Last Value (mg/l) Date of Last	306 Positive 45 24.8 Dec. '94	316 Positive 99.6 118 Mar. '00	326 Positive 95 238 Mar. '00	327 Zero 83 5.04 Mar. '00	503 Positive 75 5.67 Mar. '00	Batiste Positive 99.8 12.6 Mar. '00
Well Trend Significance (%) Last Value (mg/l) Date of Last				145 Positive 62 86.9 Dec. '93	110 Positive 85 3.9 May '00	517 Negative 55 0.6 Mar. '00
Well Trend Significance (%) Last Value (mg/l) Date of Last			134 Negative 99.6 20.2 May '00	TW-5S Zero 100 7.84 Dec. '93	111 Negative 80 8.2 May '00	TW-9S Negative 100 2.0 Nov. '00
Well Trend Significance (%) Last Value (mg/l) Date of Last				323 Positive 99.4 167 Mar. '00	325 Positive 100 13.5 Mar. '00	TW-12S Negative 35 16.1 Nov. '00
Well Trend Significance (%) Last Value (mg/l) Date of Last				323 Positive 99.4 167 Mar. '00	325 Positive 100 13.5 Mar. '00	320 Positive 99 94.8 Mar. '00

Table 4. Analytical Results for Selected Wells in Simplot Area, Discharge Area, Background and Deep Wells.

Analytical Parameter	***306***	***316***	***326***	***327***	***503***	***BATISTE***	***301***	***511***	**DEEP 508**
Ortho-Phosphate (mg/l)	28.8	51.2	77.1	6.84	4.39	4.09	0.081	0.035	0.024
Nitrate (mg/l)	1.88	13.7	19.1	3.52	5.29	6.38	0.17	2.16	1.48
Ammonia (mg/l)	0.5	0.5	0.5	0.5	4.82	2.7	0.5	0.5	0.5
Calcium (mg/l)	530	462	426	131	125	87	48	75	41.9
Magnesium (mg/l)	149.1	266.2	289.6	51.5	39.6	31.9	12.1	27.4	13.1
Sodium (mg/l)	278.6	462.7	550.4	92.3	79.5	64.9	13.5	34	27.4
Potassium (mg/l)	26.9	30.8	22.5	13	9	12.2	5.7	6	4.4
Sulfate (mg/l)	1600	1970	2130	272	286	192	15	49	50
Chloride (mg/l)	120	125	125	66	62	73	41	43	29
Bicarbonate Alkalinity (mg/l)	1320	1380	1350	364	328	236	144	298	168
Fluoride (mg/l)	0.2	0.2	0.2	1.2	1.8	0.4	0.4	0.2	0.9
Temperature (degrees C)	18.2	16.2	16.1	13.9	13.9	12.6	14.4	13.1	14
Redox (millivolts)	153	165	152	-8	210	135	170	214	217
pH	6.36	6.33	6.26	6.52	6.7	6.74	7.72	7.12	7.53
Manganese (mg/l)	0.0008	0.0091	0.0023	0.0008	0.0449	0.012	0.0008	0.0008	0.0008
Iron (mg/l)	0.055	0.101	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Aluminum (mg/l)	0.022	0.022	0.022	0.022	0.022	0.022	0.0264	0.022	0.022

Table 5. Analytical Results for Selected Wells in Astaris Area, Discharge Area, Background and Deep Wells.

Analytical Parameter	**156**	**159**	**134**	**122**	**146**	***BATISTE***	***301***	**514**	**DEEP 109**
Ortho-Phosphate (mg/l)	387	9.1	31.8	9.37	0.246	4.09	0.081	0.033	0.031
Nitrate (mg/l)	0.5	0.05	7.7	21.9	4.54	6.38	0.17	0.82	0.92
Ammonia (mg/l)	11	1.7	0.5	1	0.5	2.7	0.5	0.5	0.5
Calcium (mg/l)	186	179	116	61.5	74.5	87	48	43.3	51.2
Magnesium (mg/l)	70.2	92.6	75	36.1	25.2	31.9	12.1	43.3	15
Sodium (mg/l)	560	326.5	190.5	84.3	61	64.9	13.5	21.2	32.5
Potassium (mg/l)	1730	27.5	185.1	207.4	62.5	12.2	5.7	4.4	5.6
Sulfate (mg/l)	254	238	224	95	132	192	15	42	57
Chloride (mg/l)	417	349	322	226	89	73	41	29	30
Bicarbonate Alkalinity (mg/l)	3294	892	510	280	242	236	144	138	170
Fluoride (mg/l)	0.1	0.2	0.2	0.2	0.8	0.4	0.4	0.7	0.9
Temperature (degrees C)	15.1	16.7	17.5	21	22.5	12.6	14.4	11.6	14.8
Redox (millivolts)	-182	-138	155	119	115	135	170	168	85
pH	6.36	6.61	6.7	7.14	7.1	6.74	7.72	7.73	7.47
Manganese (mg/l)	0.9	10.823	3.16	0.4583	0.2171	0.012	0.0008	0.0008	0.0008
Iron (mg/l)	0.1	1.652	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Aluminum (mg/l)	0.022	0.022	0.022	0.022	0.022	0.022	0.0264	0.022	0.022

Table 6. Saturation Indices for Selected Wells in Simplot Area, Discharge Area, Background Wells, and Deep Well.

	Saturation Index (log (IAP/K))								
Well ID	***306***	***316***	***326***	***327***	***503***	***BATISTE***	***301***	***511***	***508***
Mineral Phase									
HYDROXYLAPATITE	6.143	6.128	5.988	3.698	4.131	3.73	3.138	-0.352	-0.291
CAHPO4:2H20 (DCPD)	-0.49	-0.368	-0.288	-1.223	-1.306	-1.396	-2.831	-3.27	-3.466
CAHPO4 (DCP)	-0.177	-0.044	0.037	-0.888	-0.971	-1.055	-2.499	-2.931	-3.133
CA3(PO4)2 (BETA) (TCP)	0.257	0.363	0.336	-1.218	-1.0043	-1.254	-2.316	-4.245	-4.046
CA4H(PO4)2:3H20 (OCP)	-1.384	-1.25	-1.202	-3.798	-3.705	-4.07	-6.479	-8.911	-8.864
MNHPO4	-0.116	1.09	0.614	-0.319	1.371	0.845	-1.491	-2.15	-2.071
RHODOCROSITE	-3.633	-2.647	-3.331	-3.782	-1.891	-2.531	-2.801	-3.168	-2.947
CALCITE	0.17	0.036	-0.093	-0.585	-0.466	-0.692	-0.031	-0.201	-0.24
ARAGONITE	0.009	-0.132	-0.262	-0.763	-0.644	-0.876	-0.207	-0.382	-0.417
GYPSUM	-0.156	-0.179	-0.194	-1.08	-1.061	-1.309	-2.472	-1.882	-2.03
ANHYDRITE	-0.439	-0.471	-0.487	-1.385	-1.366	-1.621	-2.775	-2.191	-2.335
DOLOMITE	0.097	0.109	-0.08	-1.361	-1.215	-1.63	-0.446	-0.65	-0.775
DOLOMITE (DISORDERED)	-0.481	-0.478	-0.667	-1.958	-1.812	-2.232	-1.041	-1.25	-1.371
GIBBSITE	1.977	1.895	1.74	0.833	0.922	2.189	1.838	2.361	1.96
AL(OH)3 SOIL	1.427	1.345	1.19	0.283	0.372	1.639	1.238	1.811	1.41
BOEHMITE	1.088	0.99	0.834	-0.091	-0.002	1.254	0.918	1.431	1.037
FLUORITE	-1.786	-1.939	-2.005	-0.343	0.019	-1.384	-1.449	-1.943	-0.824
FE(OH)2	-7.432	-7.266	-7.694	-6.851	-6.487	-6.365	-4.285	-5.54	-4.686
HERCYNITE	2.251	2.122	1.379	0.263	0.805	3.373	4.87	4.577	4.688
VIVIANITE	-5.308	-4.324	-5.073	-5.093	-4.849	-4.631	-4.84	-7.402	-6.403

Table 7. Saturation Indices for Selected Wells in Astaris Area, Discharge Area, Background Wells, and Deep Well.

	Saturation Index (log (IAP/K)								
Well ID	**156**	**159**	**134**	**122**	**146**	**BATISTE**	**301**	**514**	**109**
Mineral Phase									
HYDROXYLAPATITE	10.828	4.815	6.323	6.399	2.018	3.73	3.138	1.661	0.692
CAHPO4:2H20 (DCPD)	0.581	-1.053	-0.58	-1.056	-2.545	-1.396	-2.831	-3.257	-3.316
CAHPO4 (DCP)	0.91	-0.732	-0.263	-0.757	-2.253	-1.055	-2.499	-2.911	-2.986
CA3(PO4)2 (BETA) (TCP)	3.218	-0.649	0.32	0.029	-2.945	-1.254	-2.316	-3.192	-3.792
CA4H(PO4)2:3H20 (OCP)	2.499	-2.924	-1.443	-2.046	-6.439	-4.07	-6.479	-7.919	-8.421
MNHPO4	4.406	3.878	4.024	3.034	1.167	0.845	-1.491	-1.911	-1.995
RHODOCROSITE	0.409	0.751	0.127	-0.403	-0.792	-2.531	-2.801	-2.848	-3.006
CALCITE	0.707	-0.197	-0.313	-0.267	-0.25	-0.692	-0.031	-0.132	-0.21
ARAGONITE	0.534	-0.03	-0.476	-0.418	-0.397	-0.876	-0.207	-0.32	-0.384
GYPSUM	-1.393	-1.157	-1.302	-1.795	-1.534	-1.309	-2.472	-2.079	-1.913
ANHYDRITE	-1.69	-1.447	-1.589	-2.064	-1.796	-1.621	-2.775	-2.397	-2.214
DOLOMITE	1.231	-0.085	-0.541	-0.443	-0.617	-1.63	-0.446	-0.578	-0.729
DOLOMITE (DISORDERED)	0.639	-0.67	-1.143	-1.01	-1.177	-2.232	-1.041	-1.185	-1.322
GIBBSITE	3.251	2.39	2.296	1.877	1.821	2.189	1.838	1.926	1.963
AL(OH)3 SOIL	2.701	1.84	1.746	1.327	1.271	1.639	1.238	1.376	1.413
BOEHMITE	2.338	1.489	1.401	1.008	0.964	1.254	0.918	0.983	1.047
FLUORITE	-2.686	-1.972	-2.081	-2.239	-0.933	-1.384	-1.449	-0.984	-0.768
FE(OH)2	-6.012	-5.255	-6.555	-5.582	-5.627	-6.365	-4.285	-4.278	-4.816
HERCYNITE	5.93	5.156	3.72	4.075	4.012	3.373	4.87	4.869	4.617
VIVIANITE	-0.868	-0.371	-3.354	-2.651	-5.745	-4.631	-4.84	-5.677	-6.383

Table 8. Summary of Nitrate-N and total phosphorous concentrations in ground water from the East Michaud Flats area, Statewide monitoring wells.

	Average Concentrations		
Statewide Wells	NO3-N	Total P	Number of
East Side Wells	(mg/L)	(mg/L)	Observations
5.33.36ADA1	2.6	0.0011	4
5.34.20DCBB1	1.1	0.030	2
5.34.31DCA1	2.1	0.010	1
5.34.34BAA1	1.3	0.06	1
6.34.07ADA2	2.7	0.022	4
6.34.09BCB1	5.4	0.024	5
6.34.10CCD1	4.4	0.042	3
6.34.16BAB1	3.8	0.024	2
West Side Wells			
5.33.34CBC1	2.6	0.020	1
6.33.02AAA1	4.8	0.020	3
6.34.06CBD1	5.6	0.022	2
6.34.07ABD1	4.3	0.055	2
6.34.07BBC1	3.9	0.020	6

5.33.36ADA1 = 05S 33E Section 6ADA1.

Table 9. Data from Portneuf River sampling, September 13 and 14, 2000.

		Stream Wetted width (ft)	Flow (ft^3/sec)	Total suspended solids (mg/l)	Total ammonia (mg/l)	Total nitrite/nitrate (mg/l)	Total Kjeldahl nitrogen (mg N/l)	Total phosphorous (mg P/l)	Dissolved ortho phosphorous (mg P/l)	Percent of stream occluded*	Percentage of transect points w aquatic macroph or filamentous al
T-1	Above Interstate (above FMC & Swanson Springs complex)	43	77.91	10	0.014	0.014		0.044	0.008	0.00%	14.30%
T-2	Below FMC & Swanson Springs complex, above STP	62	106.53	170	0.114	1.14		1.3	0.893	18.40%	17.90%
T-3	Above STP	81.7	139.59	4	0.417	2.53		2.07	1.93	7.70%	75.00%
T-4	Below STP	85.7	181.3	2	0.377	2.6		2.06	1.88	31.00%	70.00%
T-6	Above Batiste Springs Trout Farm discharge	62.2	91.74	2	0.382	2.71	0.49	1.9	1.8	34.20%	85.00%
T-7	Below Batiste Springs Trout Farm discharge	97	164.88	2	0.292	2.62	0.44	1.47	1.36	38.90%	52.20%
T-8	Between Batiste and Papoose Springs	94.3	254.11	5	0.23	2.7	0.42	1.45	1.33	1.30%	60.90%
T-9	Above Papoose Springs	86.1	276.25	2	0.275	2.71	0.4	1.44	1.35	5.50%	100.00%
T-10	Below Papoose Springs	105.8	264.36	2	0.167	2.71	0.24	1.21	1.18	20.10%	72.00%
	STP (9/12/00 - flow = 5.02mgd)		0.129		5.14	9.3	6.3	0.8	0.54		
	STP (9/1300 - flow = 1.66mgd)		0.043		1.82	9					
	STP (9/14/00 - flow = 1.97mgd)		0.051		1.83	7.9					

* percent of stream which has emergent vegetation from each streambank
STP = City of Pocatello Wastewater Treatment Plant discharge to Portneuf River

Table 10. Portneuf River transect nutrient loading calculations for data collected September 13 and 14, 2000

Sample Location	Nitrogen loading Ammonia (lbs/day)	TKN (lbs/day)	nitrite/nitrate (lbs/day)	Nitrogen (Ammonia + nitrite/nitrate) loading (lbs/day)	Total phosphate loading (lbs/day)
T-1	6		6	12	18
T-2	66		655	721	747
T-3	314		1905	2219	1559
T-4	369		2543	2911	2015
T-6	189	242	1341	1530	940
T-7	260	391	2330	2590	1307
T-8	315	576	3701	4016	1988
T-9	410	596	4038	4448	2146
T-10	238	342	3864	4103	1725
STP 9/12/00	4		6	10	1
STP 9/13/00	0.4		2	3	
STP 9/14/00	1		2	3	

Table11. Daily loading calculations for nitrogen and phosphorous from City of Pocatello wastewater treatment plant.

Month	Nitrogen loading ammonia (lbs/day)	TKN (lbs/day)	nitrite/nitrate (lbs/day)	TKN + NO2/NO3 loading (lbs/day)	Total P loading (lbs/day)
March-01	16	119	395	514	44
February-01	430	608	364	972	86
January-01	1018	1979	231	2210	45
December-00	504	602	416	1018	58
November-00	300	331	589	920	58
October-00	254	340	755	1095	50
September-00					
August-00	320	340	386	726	39
July-00	35	1636	694	2330	80
June-00	18	69	309	379	16
May-00	25	146	651	797	89
April-00	15	82	810	892	266
March-00	10	105	531	636	47
February-00	12	103	419	522	53
January-00	77	196	510	706	127

Loadings calculated from average daily flow and average daily nutrient concentration

Table 12 . Batise Spring channel analytical data for the period May 4, 1999 through December 7, 2000.

Date	site	chloride	sulfate	CaCO3 (alkalinity)	TDS	Ammonia	KN	no2+no3	total N	total P	TSS	ortho-P	turbidity (NTU)	ortho-P nonfiltered	CaCO3 hardness
12/07/2000	springhouse	48	119	225	na	1.2	1.3	5.05	6.35	5.85	<10	6.1	0.238		322
12/07/2000	loading dock	27	52	199	na	<0.1	<0.5	2.27	2.27	0.39	<10	0.79	0.098		229
12/07/2000	culvert	29	54	216	na	<0.1	<0.5	2.59	2.59	0.63	<10	0.91	0.202		248
12/07/2000	spillway	28	53	218	na	<0.1	<0.5	2.54	2.54		<10	0.9	0.46		249
12/07/2000	hatchery	28	53	216	na	0.2	<0.5	2.55	2.55	0.55	<10	0.92	0.429		246
12/07/2000	hatchery 2	28	51	217	na	0.1	<0.5	2.59	2.59	0.53	<10	0.67	1.02		252
11/08/2000	springhouse	51	126	217	534	1.3	1.3	5.46	6.8	7.44	<10	6.55	0.212		
11/08/2000	loading dock	28	51	198	339	<0.1	<0.5	2.28	2.3	0.41	<10	0.79	0.293		
11/08/2000	culvert	32	57	217	372	<0.1	<0.5	2.68	2.7	0.83	<10	0.85	0.287		
11/08/2000	spillway	30	56	206	362	<0.1	<0.5	2.64	2.6	0.86	<10	0.95	0.455		
11/08/2000	hatchery	27	51	221	367	0.2	1.1	2.63	3.7	0.86	<10	1.1	0.731		
10/10/2000	springhouse A	49	124	229	535	1.3	1.6	6.02	7.6	7.24	<10	5.95	0.192		
10/10/2000	springhouse B	26	<1	<1	121	4.4	4.5	15.5	20	4.09	<10				
10/10/2000	loading dock	25	47	201	331	<0.1	0.6	2.17	2.2	0.21	<10	0.27	0.124		
10/10/2000	culvert	28	54	219	365	<0.1	<0.5	2.91	2.9	0.88	<10	1.05	0.351		
10/10/2000	spillway	28	53	223	366	<0.1	<0.5	2.84	2.8	0.81	<10	0.87	0.392		
10/10/2000	hatchery	28	52	219	367	0.2	0.5	2.82	2.9	0.82	<10	0.85	0.792		
09/06/2000	springhouse	38	83	214	425	0.2	<0.5	3.82	3.8	3.24	<10	0.64	0.32		
09/06/2000	loading dock	24	44	223	333	<0.1	<0.5	2.39	2.4	0.04	<10	0.42	0.39		
09/06/2000	culvert	26	47	227	343	<0.1	<0.5	2.43	2.4	0.21	<10	0.44	0.24		
09/06/2000	spillway	25	47	229	342	<0.1	<0.5	2.37	2.4	0.18	<10	0.41	0.46		
09/06/2000	hatchery	26	47	230	347	0.2	0.5	2.33	2.83	0.24	<10	0.48	0.93		
08/08/2000	springhouse	35	69	209	374	<0.1	<0.5	2.85	2.9	1.78	15	0.38	1.17		
08/08/2000	loading dock	24	44	210	309	<0.1	<0.5	2.19	2.2	0.03	<10	0.27	0.253		
08/08/2000	culvert	25	45	225	325	<0.1	<0.5	1.61	1.6	0.06	<10	0.41	0.149		
08/08/2000	spillway	26	45	225	347	<0.1	<0.5	2.1	2.1	0.07	<10	0.73	0.674		
08/08/2000	hatchery	25	45	228	331	0.2	0.6	2	2.6	0.17	<10	0.37	0.81		
07/12/2000	springhouse	36	78	210	420	<0.1	<0.5	2.67	2.7	2.15	<10	2.4	0.278		
07/12/2000	loading dock	22	40	187	321	<0.1	<0.5	1.97	2	0.02	<10	0.24	0.238		
07/12/2000	culvert	24	42	200	341	<0.1	<0.5	1.88	1.9	0.07	<10	0.25	0.458		
07/12/2000	spillway	24	42	215	348	<0.1	<0.5	1.85	1.9	0.07	<10	0.25	0.404		
07/12/2000	hatchery	24	42	210	349	0.2	0.5	1.82	2.3	0.14	<10	0.45	0.396		
06/14/2000	springhouse	46	124	224	507	<0.1	0.8	4.35	5.15	4.7	<10	4	0.389		
06/14/2000	loading dock	24	45	190	305	<0.1	0.6	1.67	2.27	0.13	<10	0.4	0.689		
06/14/2000	culvert	26	49	210	326	<0.1	<0.5	2.15	2.2	0.3	<10	0.45	0.571		

Table 12 . Batise Spring channel analytical data for the period May 4, 1999 through December 7, 2000 (con't)

date	*site*	*chloride*	*sulfate*	*CaCO3 (alkalinity)*	*TDS*	*Ammonia*	*KN*	*no2+no3*	*total N*	*total P*	*TSS*	*ortho-P*	*turbidity (NTU)*	*ortho-P nonfiltered*	*CaCO3 hardness*
06/14/2000	hatchery	26	49	221	339	1.4	2.6	1.89	4.49	0.63	13	0.65	3.76		
04/04/2000	springhouse											7.4			
04/04/2000	loading dock											0.18			
04/04/2000	culvert											5.8			
04/04/2000	spillway	34	74	230	409	0.2	<0.5	3.6	3.6	2	<10	5.7			
04/04/2000	hatchery	35	72	229	407	0.3	<0.5	3.6	3.6	2.17	<10	4.9			
03/03/2000	springhouse											10.8	0.524		
03/03/2000	loading dock											2.2	0.513		
03/03/2000	culvert											2.4	0.404		
03/03/2000	spillway	34	76	228	422	0.4	<0.5	3.76	3.8	2.64	<10 (1)	2.1	0.462		
03/03/2000	hatchery	34	77	231	423	0.5	0.5	3.79	4.29	2.51	<10 (1)	2.2	0.667		
02/09/2000	springhouse											1.44	1		
02/09/2000	loading dock											0.21	0.2		
02/09/2000	culvert											0.92	0.3		
02/09/2000	spillway	30	61	221	381	0.1	<0.5	2.94	2.9	1.05	<10 (2)	0.85	1		
02/09/2000	hatchery	31	61	221	380	0.2	<0.5	2.92	2.9	1.09	<10 (3)	1.1	1.3		
01/11/2000	springhouse											8.1	0.67		
01/11/2000	loading dock											0.1	0.52		
01/11/2000	culvert											0.96	0.44		
01/11/2000	spillway	33	62	222	379	0.2	<0.5	2.98	3	1.09	<10 (<1)	0.96	0.6		
01/11/2000	hatchery	31	62	223	380	0.3	<0.5	2.99	3	1.04	<10 (<1)	1	1.16		
12/01/1999	springhouse	56	188	262	671	3.8	3.8	8.67	12.5	9.4	<10 (<1)	10.4	0.6		
12/01/1999	loading dock	26	45	203	300	<0.1	<0.5	2.09	2.1	0.02	<10 (<1)	0.09	0.2		
12/01/1999	culvert a	33	65	222	371	0.3	<0.5	3.19	3.2	1.25	<10 (3)	1.2	0.5		
12/01/1999	culvert b	33	66	227	366	0.3	<0.5	3.17	3.2	1.14	<10 (1)	1.15			
12/01/1999	spillway	33	65	228	365	0.2	<0.5	3.17	3.2	1.1	<10 (<1)	1.1	0.8		
12/01/1999	hatchery	34	66	229	355	0.3	0.6	3.18	3.8	1.28	<10 (1)	1.06	1.3		
11/03/1999	springhouse	53	185	280	702	3.7	3.8	8.54	12.3	8.36	<10 (<1)	7.4	0.22		
11/03/1999	loading dock	22	43	206	312	<0.1	<0.5	2.1	2.1	0.02	<10 (<1)	0.06	0.38		
11/03/1999	culvert	29	65	228	388	0.2	<0.5	3.17	3.2	1.13	<10 (<1)	0.96	0.16		
11/03/1999	spillway	29	63	230	385	0.2	<0.5	3.14	3.1	1.1	<10 (<1)	0.98	0.47		
11/03/1999	hatchery	29	63	231	387	0.3	<0.5	3.14	3.1	1.05	<10 (3)	0.96	0.69		
10/19/1999	springhouse	56	191	283	716	3.7	3.8	8.59	12.39	8.72	<10 (<1)	0.8	0.3		
10/19/1999	loading dock	24	47	204	321	<0.1	<0.5	2.07	2.07	0.37	<10 (1)	0.22	0.49		
10/19/1999	culvert	30	64	231	373	0.3	<0.5	3.09	3.09	1.1	<10 (<1)	0.94	0.25		
10/19/1999	spillway	29	63	228	383	0.2	<0.5	3.03	3.03	0.97	<10 (1)	0.44	0.71		
10/19/1999	hatchery	30	63	231	372	0.3	<0.5	3.01	3.01	0.98	<10 (<1)	0.46	0.76		
09/23/1999	springhouse	47	149	271	640	2.7	3.5	7.41	10.9	7.48	<10 (<1)	6	0.15		
09/23/1999	loading dock	23	44	205	314	<0.1	<0.5	2.09	2.1	0.02	<10 (<1)	0.06	0.28		

Table 12. Batise Spring channel analytical data for the period May 4, 1999 through December 7, 2000 (concluded).

date	*site*	*chloride*	*sulfate*	*CaCO3 (alkalinity)*	*TDS*	*Ammonia*	*KN*	*no2+no3*	*total N*	*total P*	*TSS*	*ortho-P*	*turbidity (NTU)*	*ortho-P nonfiltered*	*CaCO3 hardness*
09/23/1999	spillway	27	57	230	376	0.2	<0.5	2.76	2.8	0.7	<10 (<1)	0.63	0.4		
09/23/1999	hatchery	27	57	231	375	0.3	<0.1	2.66	2.7	0.86	<10 (3)	0.64	0.74		
08/10/1999	springhouse	na	na	218	468	0.5	0.5	4.3	4.8	2.8	<10 (<1)	3	0.01		
08/10/1999	loading dock	na	na	185	311	<0.1	<0.5	1.82	1.8	0.02	<10 (<1)	0.06	0.07		
08/10/1999	culvert	na	na	209	350	<0.1	<0.5	2.18	2.2	0.15	<10 (2)	0.21	0.15		
08/10/1999	spillway	na	na	198	353	<0.1	<0.5	2.09	2.1	0.17	<10 (2)	0.23	0.27		
08/10/1999	hatchery	na	na	218	344	0.1	<0.5	2.01	2	0.2	<10 (2)	0.23	0.56		
07/15/1999	springhouse	na	na	240	585	<0.1	<0.5	0.21	0.21	4.87	<10 (5)	4.4	0.24		
07/15/1999	loading dock	na	na	189	321	<0.1	<0.5	1.81	1.81	0.04	<10 (<1)	0.08	0.11		
07/15/1999	culvert	na	na	211	357	<0.1	<0.5	2.34	2.34	0.25	<10 (<1)	0.32	0.36		
07/15/1999	spillway	na	na	na	na	<0.1	<0.5	2.28	2.28	0.25	na	0.26	0.26		
07/15/1999	hatchery	na	na	216	364	0.2	0.6	2.25	2.85	0.31	<10 (6)	0.31	0.85		
06/03/1999	springhouse	77	325	377	1020	6.3	6.5	11.9	18.4	14.7	<10 (<1)		0.18	12.4	
06/03/1999	loading dock	40	121	238	514	0.9	1.1	5.81	6.9	3.58	<10 (<1)		0.15	3.2	
06/03/1999	culvert	41	133	267	549	1.2	1.3	5.45	6.8	4.3	<10 (<1)		0.17	3.8	
06/03/1999	spillway	41	129	262	549	1	1.3	5.4	6.7	4.08	<10 (<1)		0.24	3.6	
06/03/1999	hatchery	40	128	256	552	1.1	1.3	5.44	6.7	4.28	<10 (<1)		0.33	3.5	
05/04/1999	springhouse	63	274	353	1000	2.22	5.09	9.68	14.77	16.1	<2	13.4	0.1		
05/04/1999	loading dock	31	73	195	400	<0.04	0.36	3	3.36	1.02	<2	1.4	0.19		
05/04/1999	culvert	38	123	248	532	<0.04	0.58	3.78	4.36	3.44	<2	3.9	0.12		
05/04/1999	spillway	37	117	242	522	0.38	0.37	4.33	4.7	3.32	<2	3.7	0.23		
05/04/1999	hatchery	37	117	245	522	1.13	1.27	4.42	5.69	3.44	<2	3.8	0.45		

Table 13. Average NO3-N and orthophosphate concentrations for three monitoring wells at Simplot Swanson wastewater land application acreage.

Well Number	Upgradient/ Downgradient	Ave. NO3-N (mg/L)	Ave. Ortho-P (mg/L)	Number of Observations
509	Downgradient	3.23	0.11	9
511	Downgradient	2.30	0.045	5
513	Upgradient	3.40	0.037	5

Table 14. Flow, orthophosphate and NO3-N loading calculations from the shallow aquifer, Astaris/Simplot facilities, to the Portneuf River.

					Concentration		**Load**	
Well	Model K (ft/d)	I (ft/ft)	Area (ft2)	Q (ft3/day)	O-P* (mg/L)	NO3-N (mg/L)	O-P (lbs/d)	NO3-N (lbs/d)
502	1700	5.24e-4	1.44e4	12544	0.1	3.3	0.1	3
517	9940	6.45e-4	1.28e4	82085	1	9.73	3	50
331	9940	7.14e-4	1.60e4	114872	29	31.8	204	228
335S	1700	8.13e-4	2.20e4	30130	95	194	178	365
327	1700	1.47e-4	3.28e4	81180	5	3.14	26	16
318	1700	1.47e-4	2.04e4	51282	47	2.1	150	7
Totals				**372,093**			**562**	**668**

*O-P = orthophosphate.

Figures

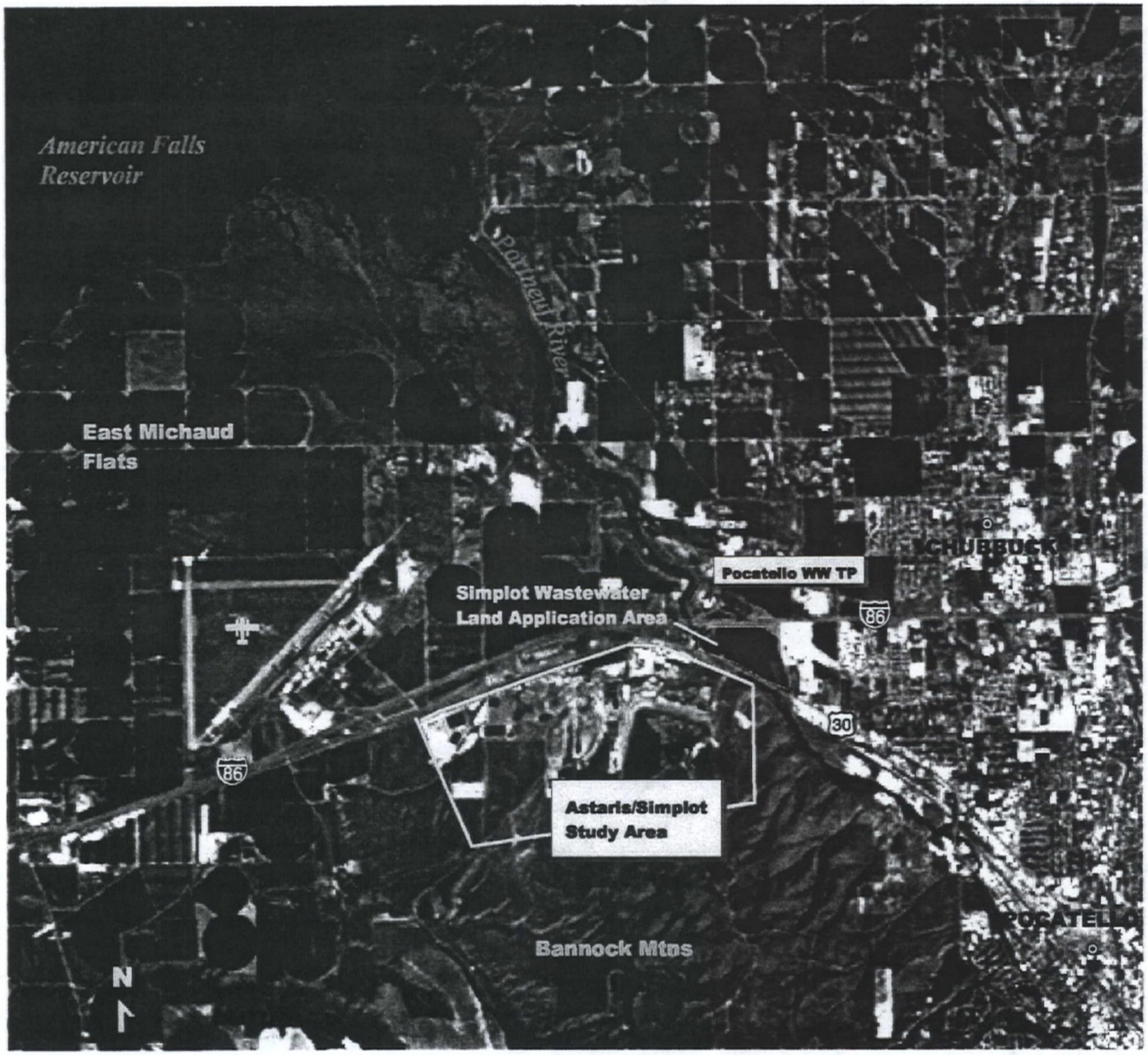


Figure 1. Air photo showing features in the East Michaud Flat and Astaris/Simplot study area.

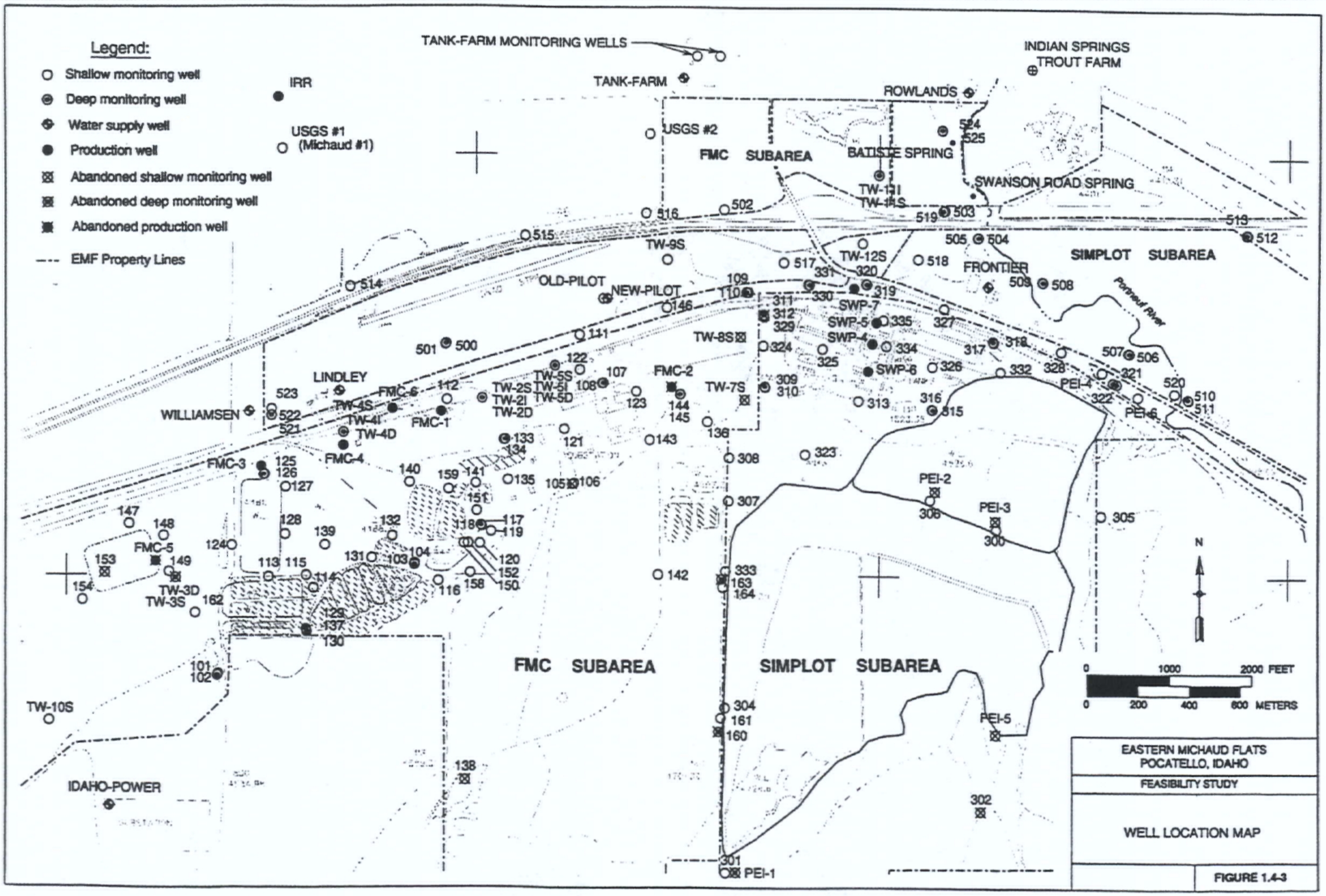


Figure 2. Locations of deep and shallow monitoring wells and production wells at the Astaris/Simplot site. (Adapted from Bechtel Environmental Inc., June 1994.)

Figure 3. Ground water flow directions for aquifers east and west of the Portneuf River. Flow directions based on potentiometric maps from West and Kilburn, 1976, Plate 1, Jacobson, 1982 and Bechtel Environmental, Inc, June 1994.

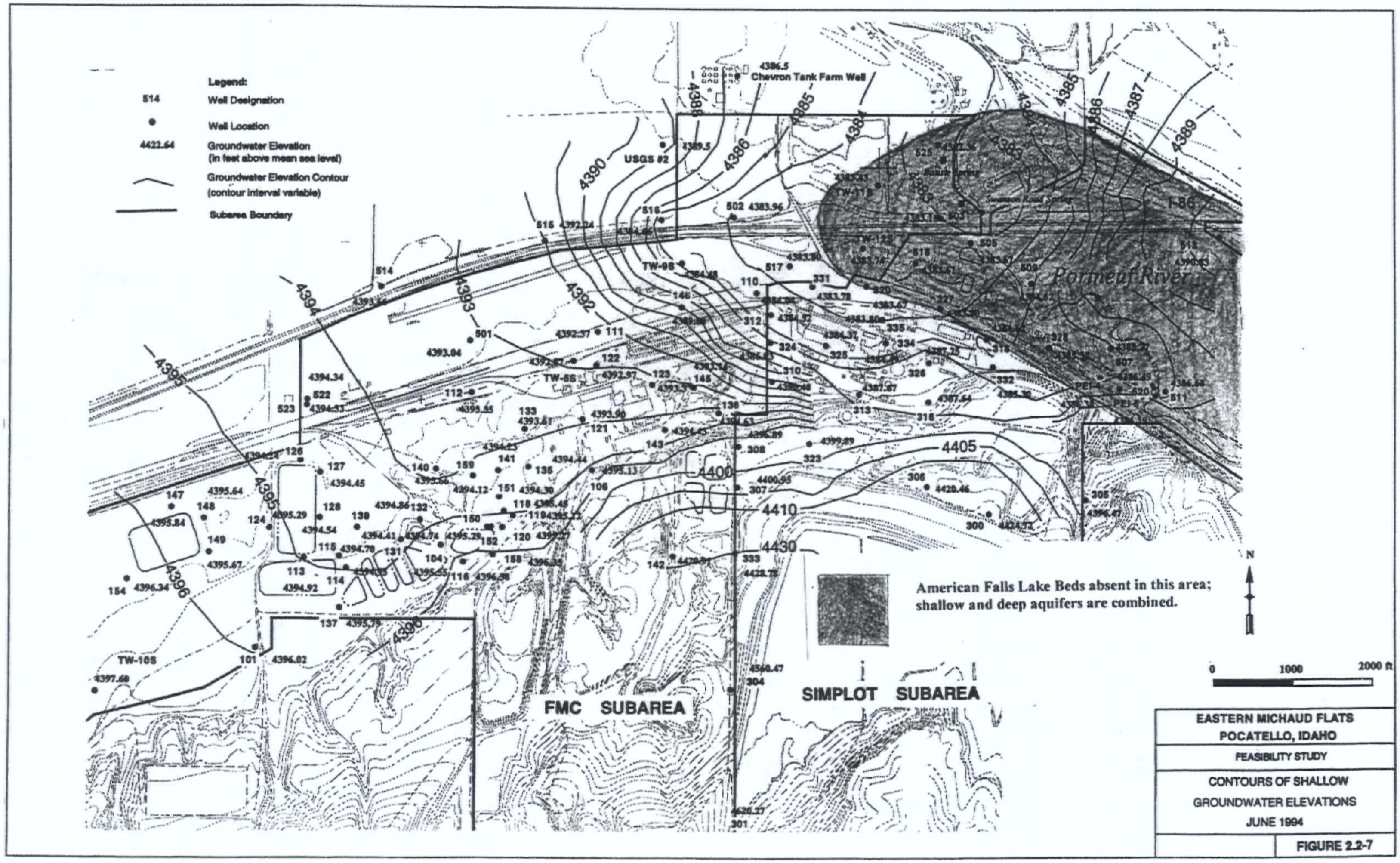


Figure 4. Potentiometric map for the shallow aquifer for the Astaris/Simplot site. Shaded region represents area where American Falls Lake Beds are absent. Shallow and deep aquifers are combined in shaded area. (Adapted from Bechtel Environmental Inc., 1994)

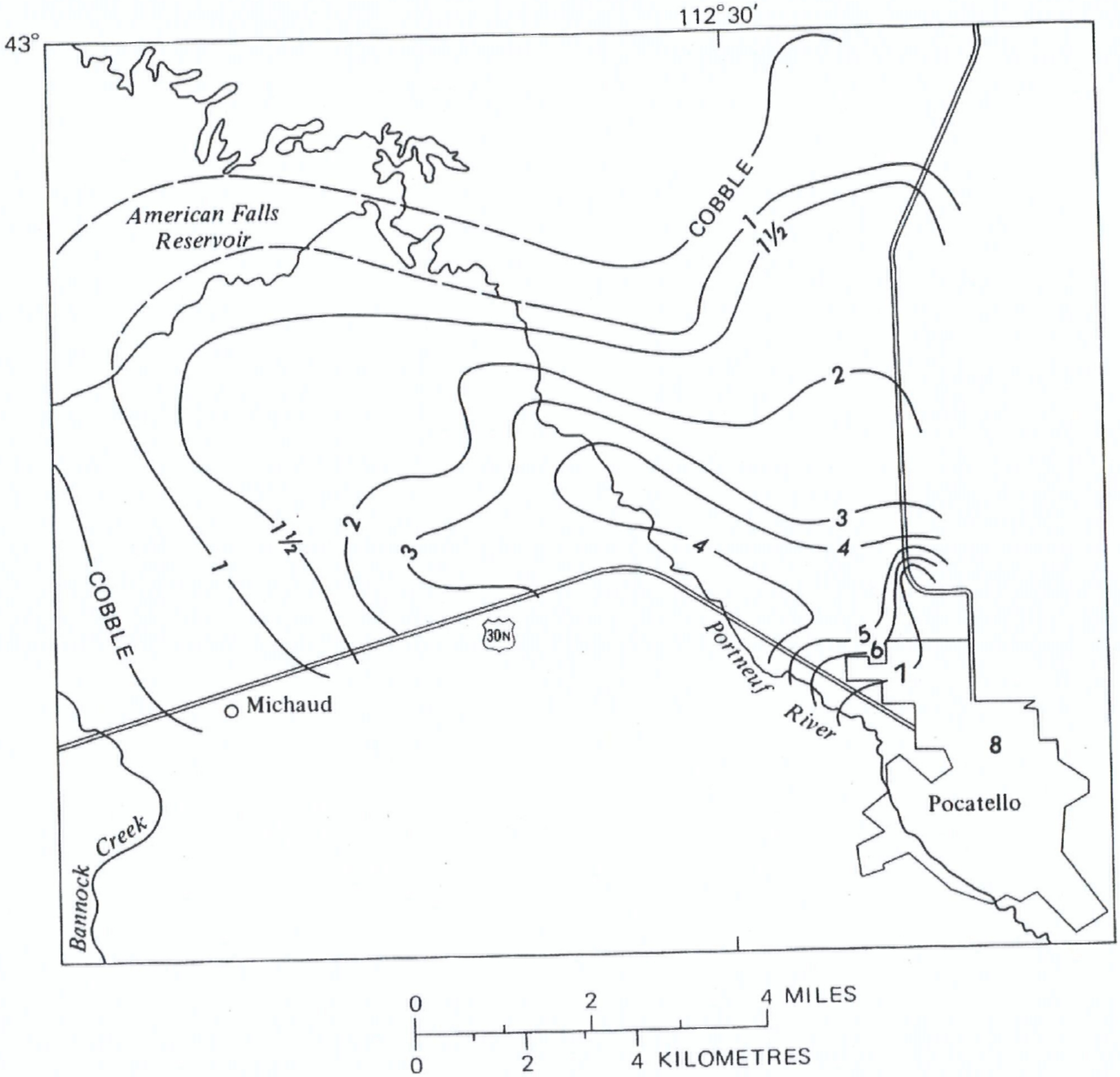


Figure 5. Areal variation in maximum boulder size in the Michaud gravels (contours in feet of longest dimension of largest boulders). Adapted from Trimble, 1976.

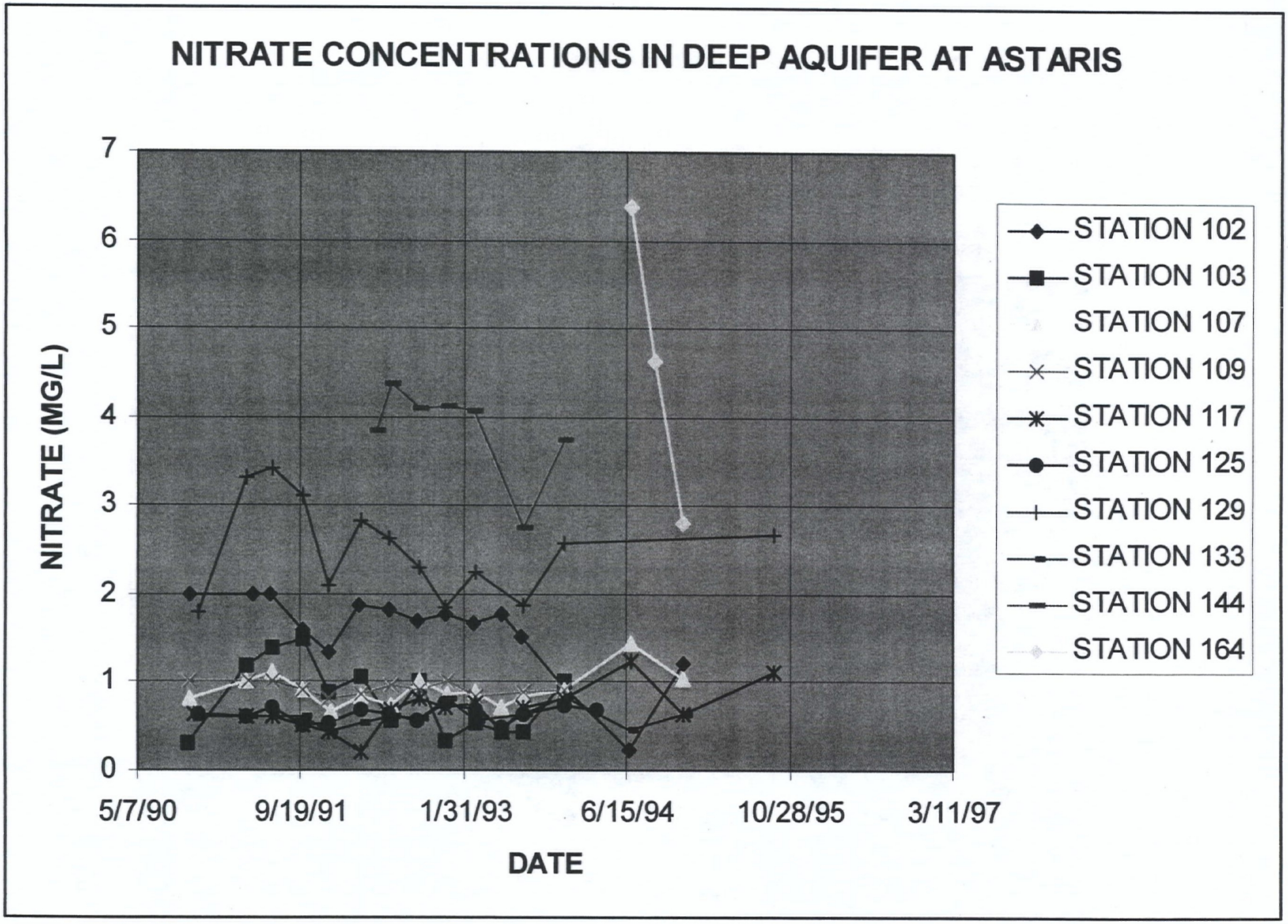


Figure 6. Time Series Plot of Nitrate Concentration in Selected Deep Aquifer Wells at the Astaris Facility.

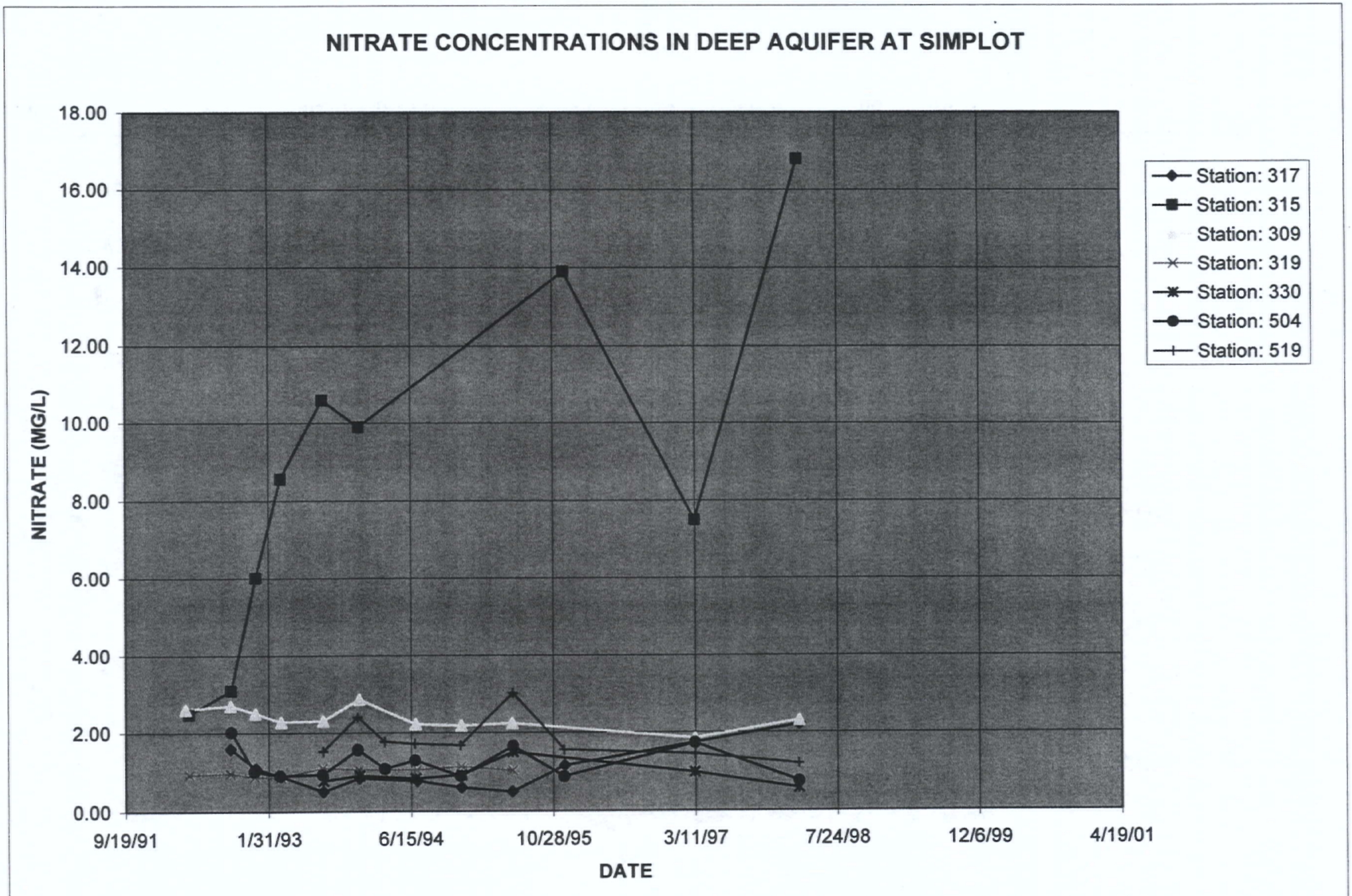


Figure 7. Time Series Plot of Nitrate Concentration in Selected Deep Aquifer Wells at the Simplot Facility.

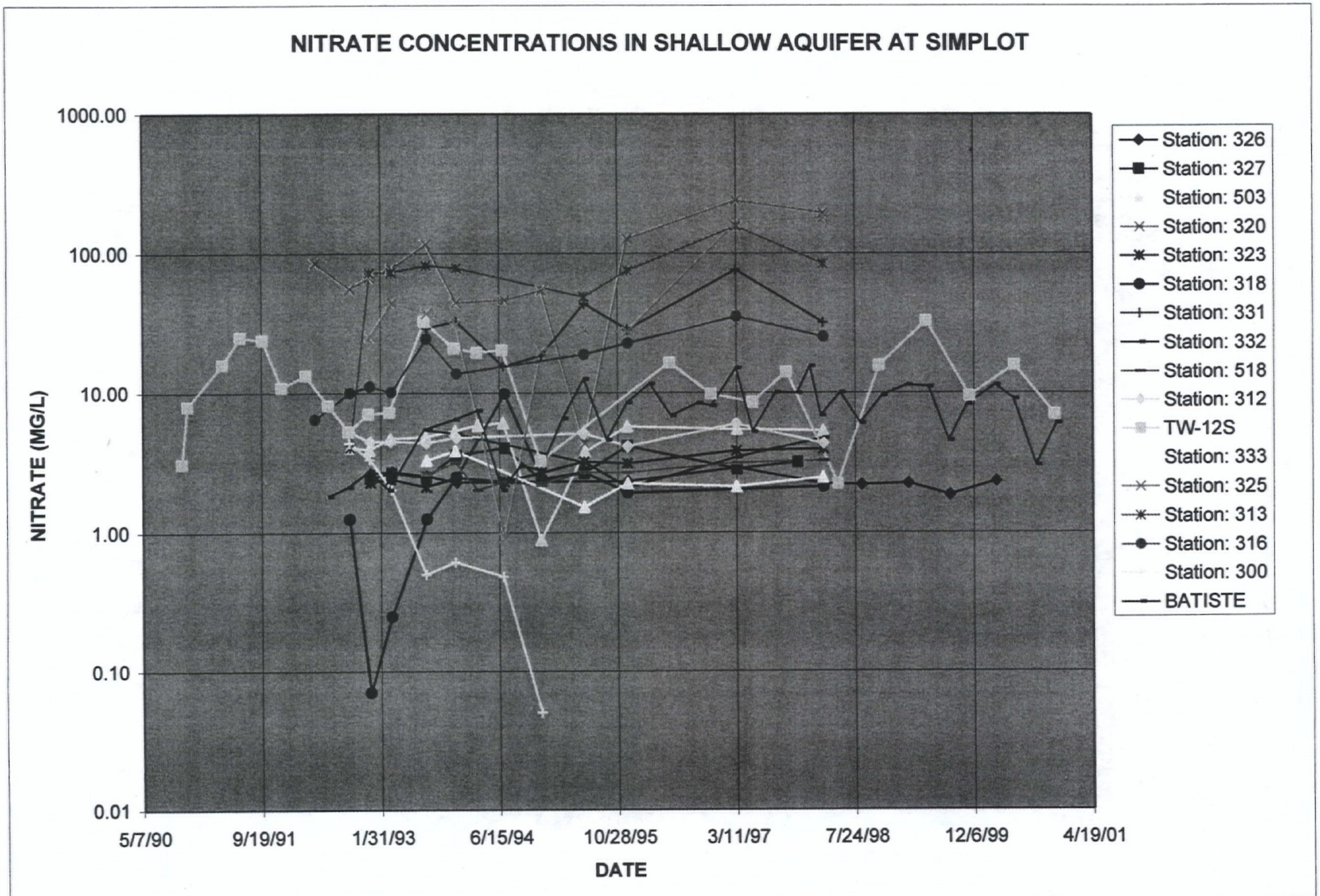


Figure 8. Time Series Plot of Nitrate Concentration in Selected Shallow Aquifer Wells at the Simplot Facility.

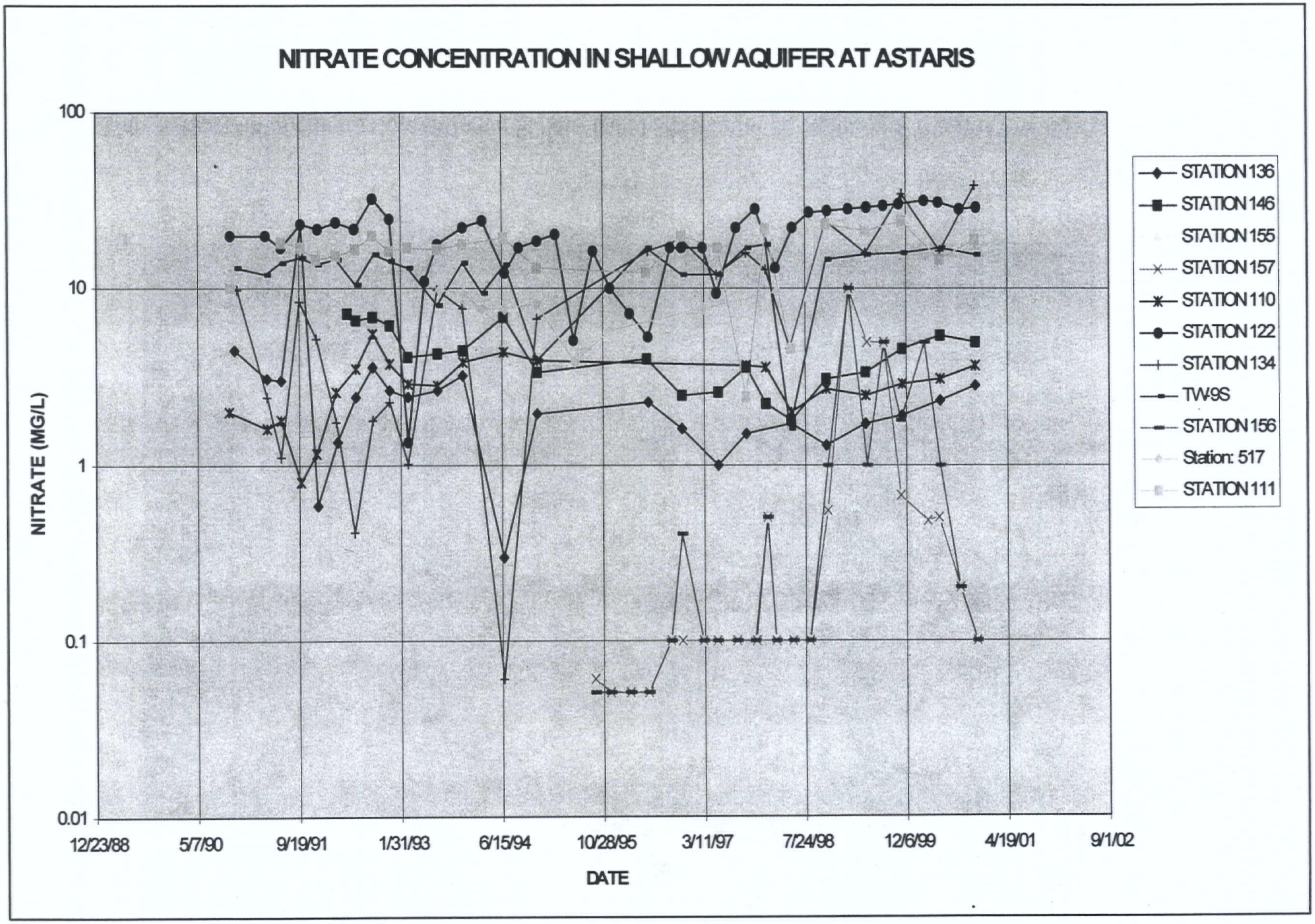


Figure 9. Time Series Plot of Nitrate Concentration in Selected Shallow Aquifer Wells at the Astaris Facility.

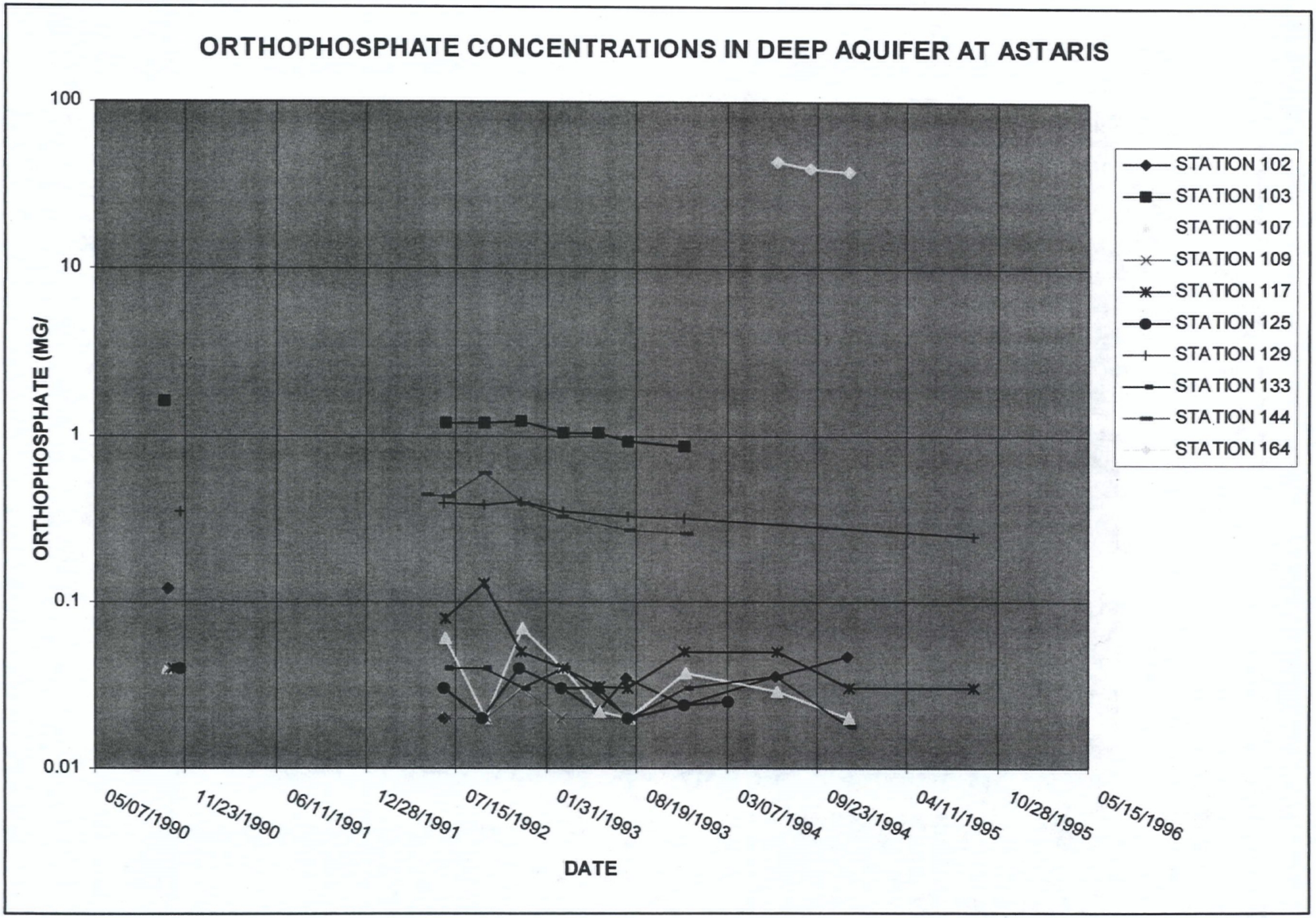


Figure 10. Time Series Plot of Orthophosphate Concentration in Selected Deep Aquifer Wells at the Astaris Facility.

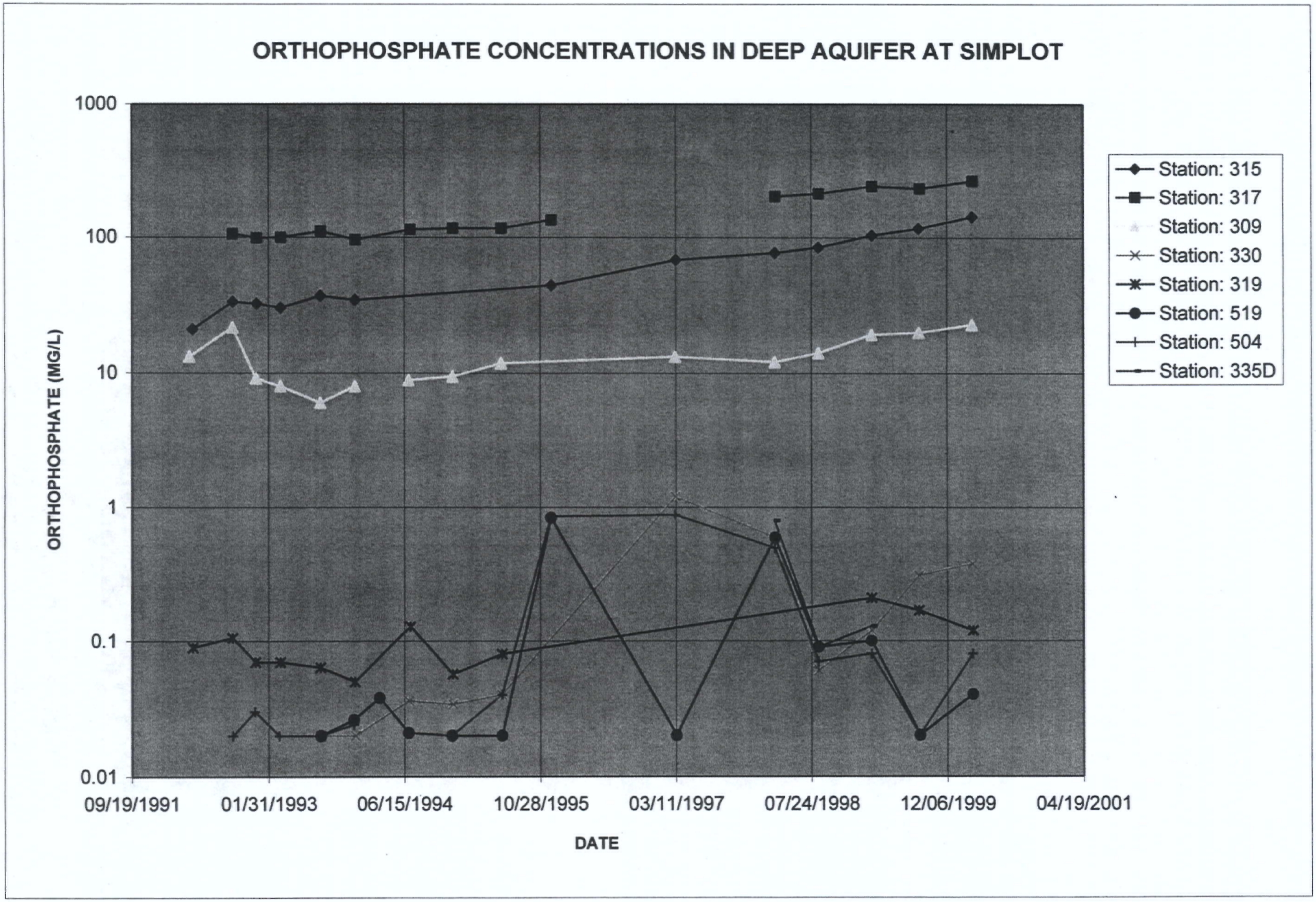


Figure 11. Time Series Plot of Orthophosphate Concentration in Selected Deep Aquifer Wells at the Simplot Facility.

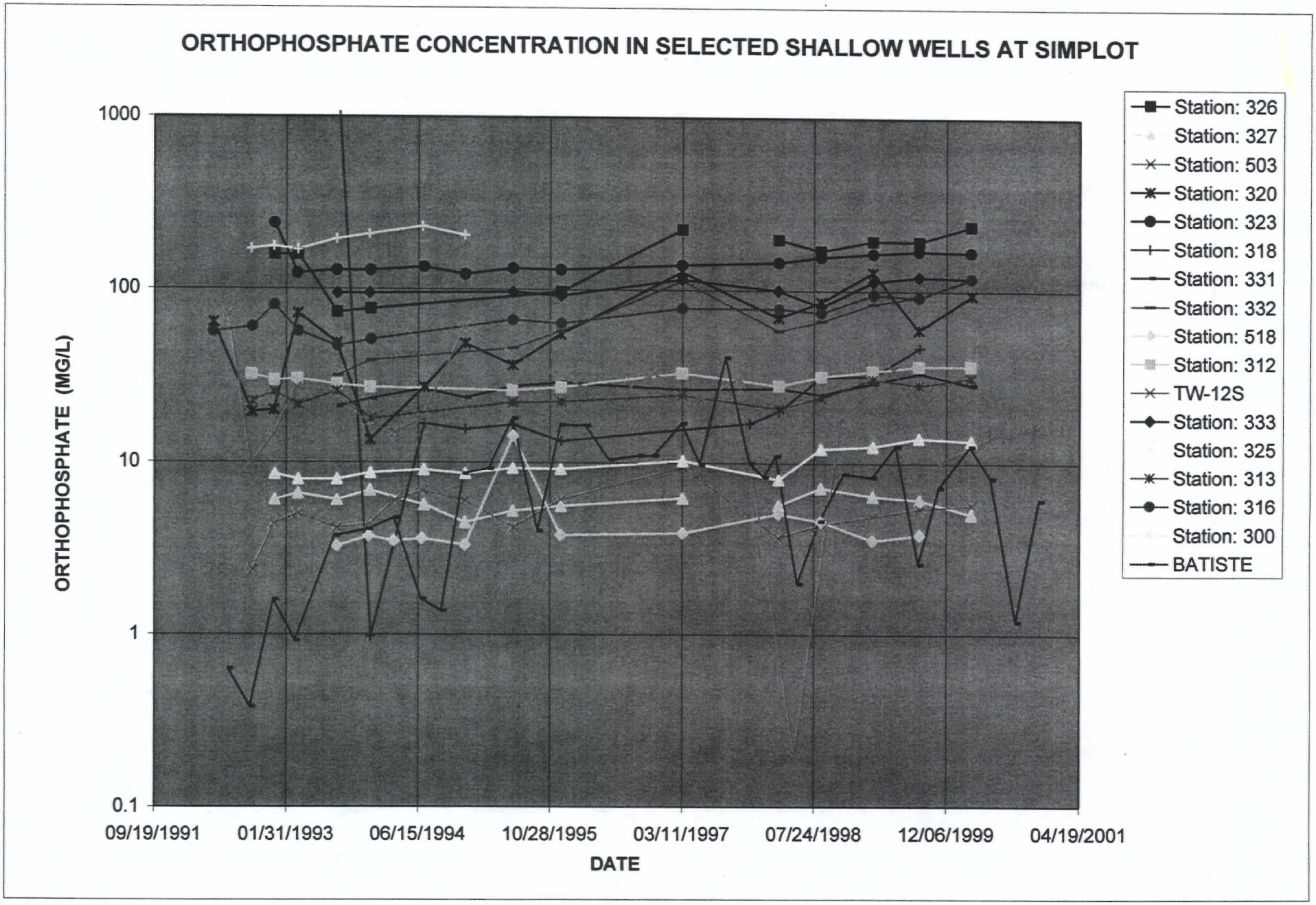


Figure 12. Time Series Plot of Orthophosphate Concentration in Selected Shallow Aquifer Wells at the Simplot Facility.

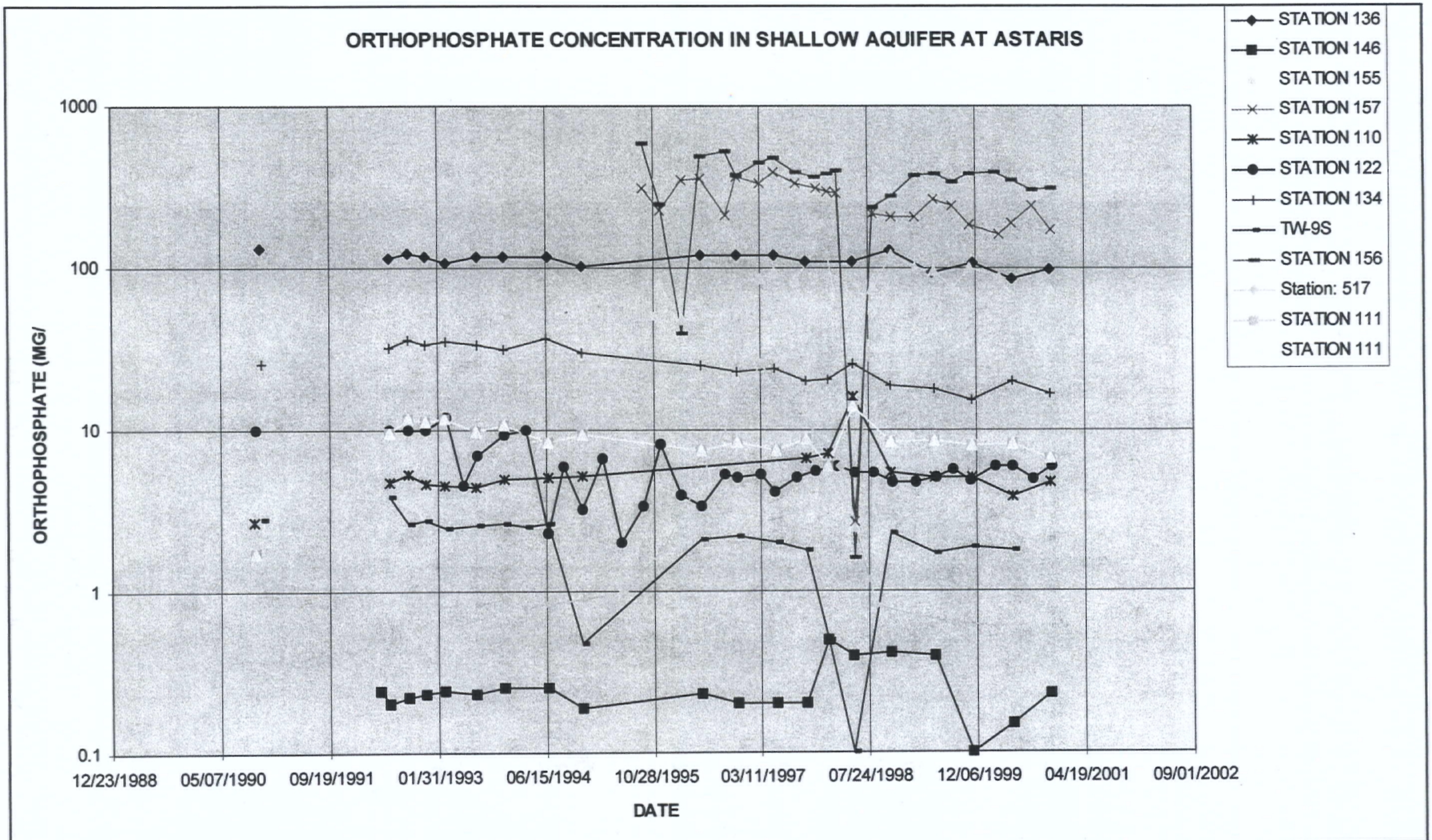


Figure 13. Time Series Plot of Orthophosphate Concentration in Selected Shallow Aquifer Wells at the Astaris Facility.

Figure 14. Groundwater flowpaths used in geochemical analysis and orthophosphate concentrations in the shallow aquifer based on sampling conducted in March 1993.

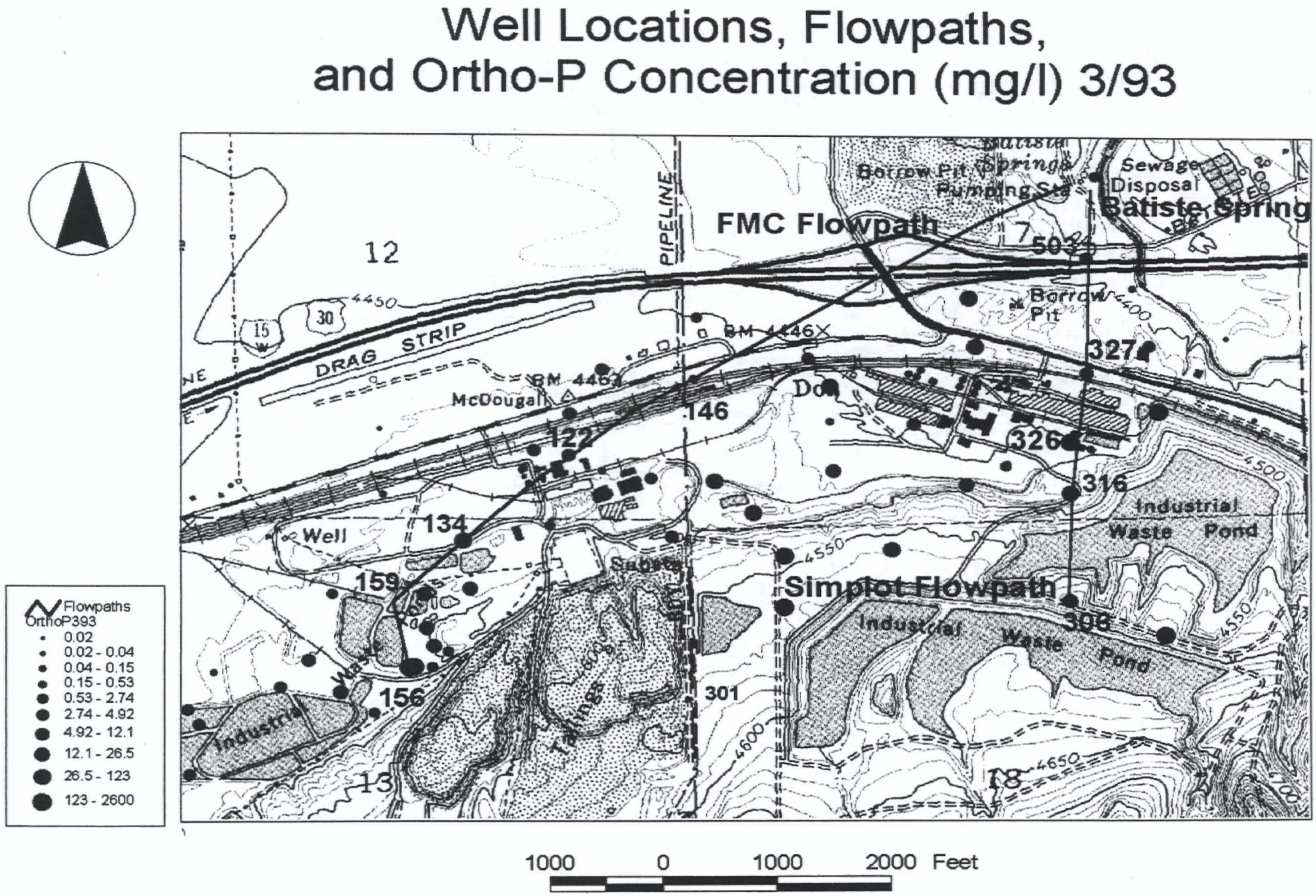
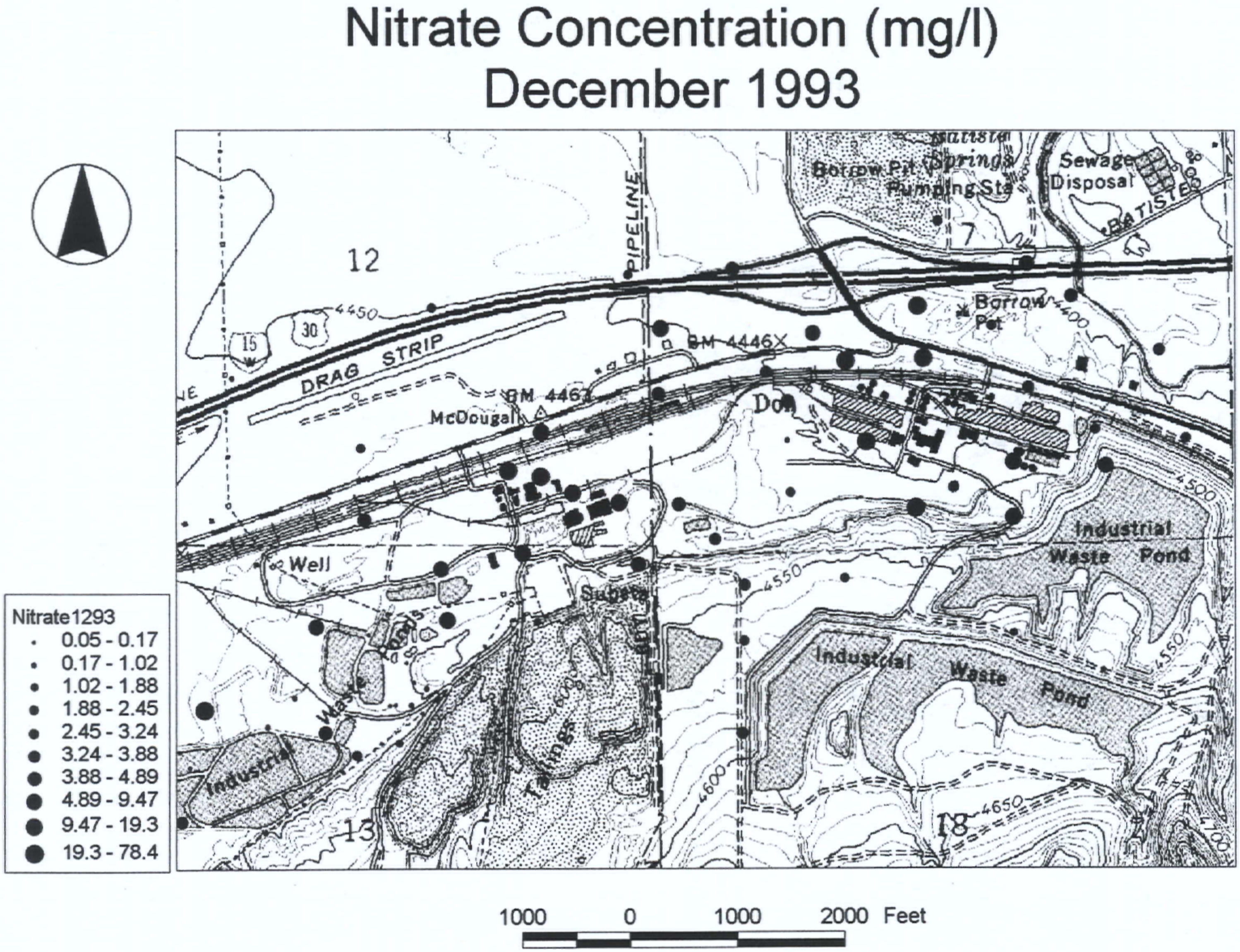


Figure 15. Nitrate concentrations in the shallow aquifer based on samples collected in December 1993.



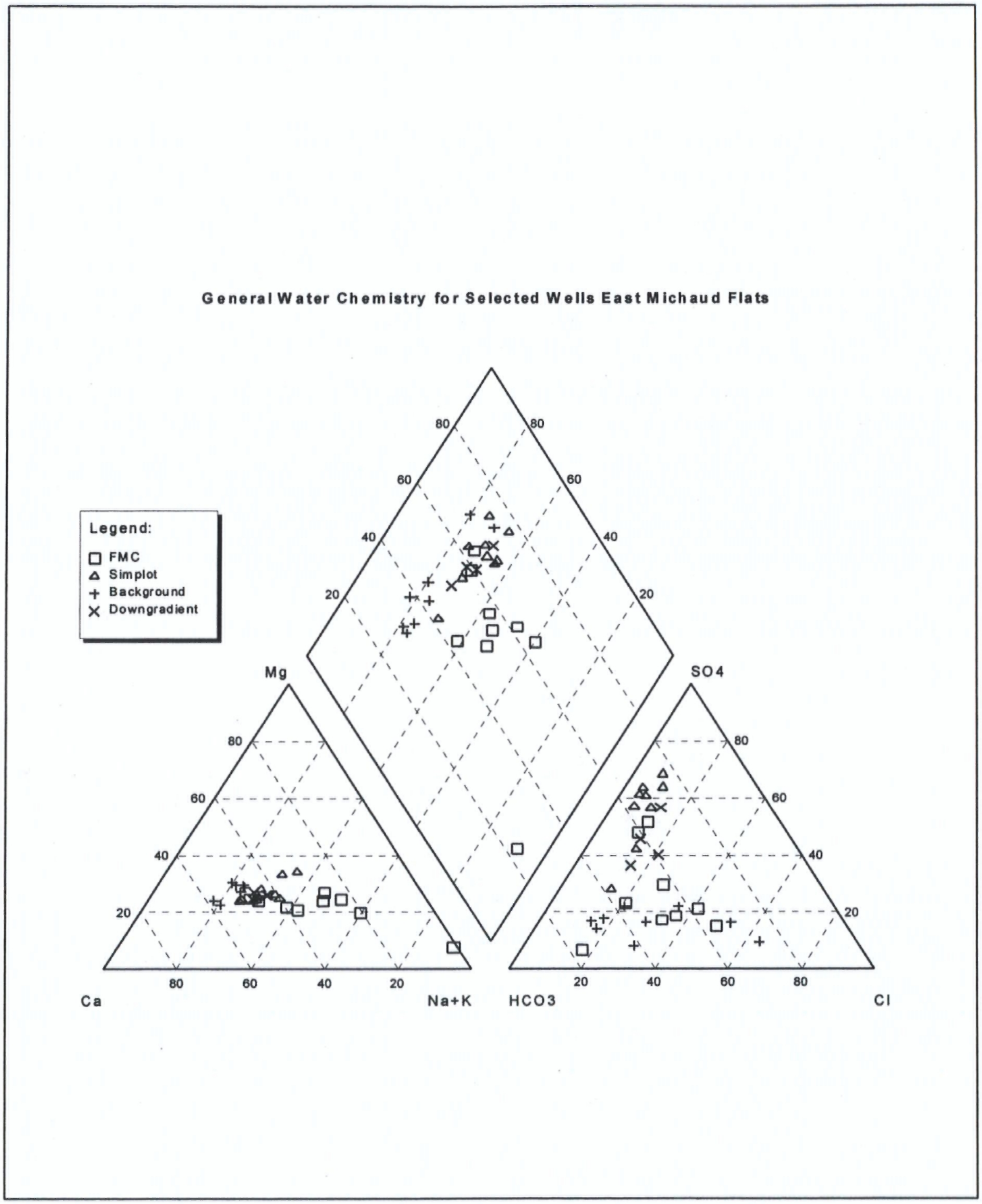


Figure 16. Piper Diagram for Selected Wells in East Michaud Flats.

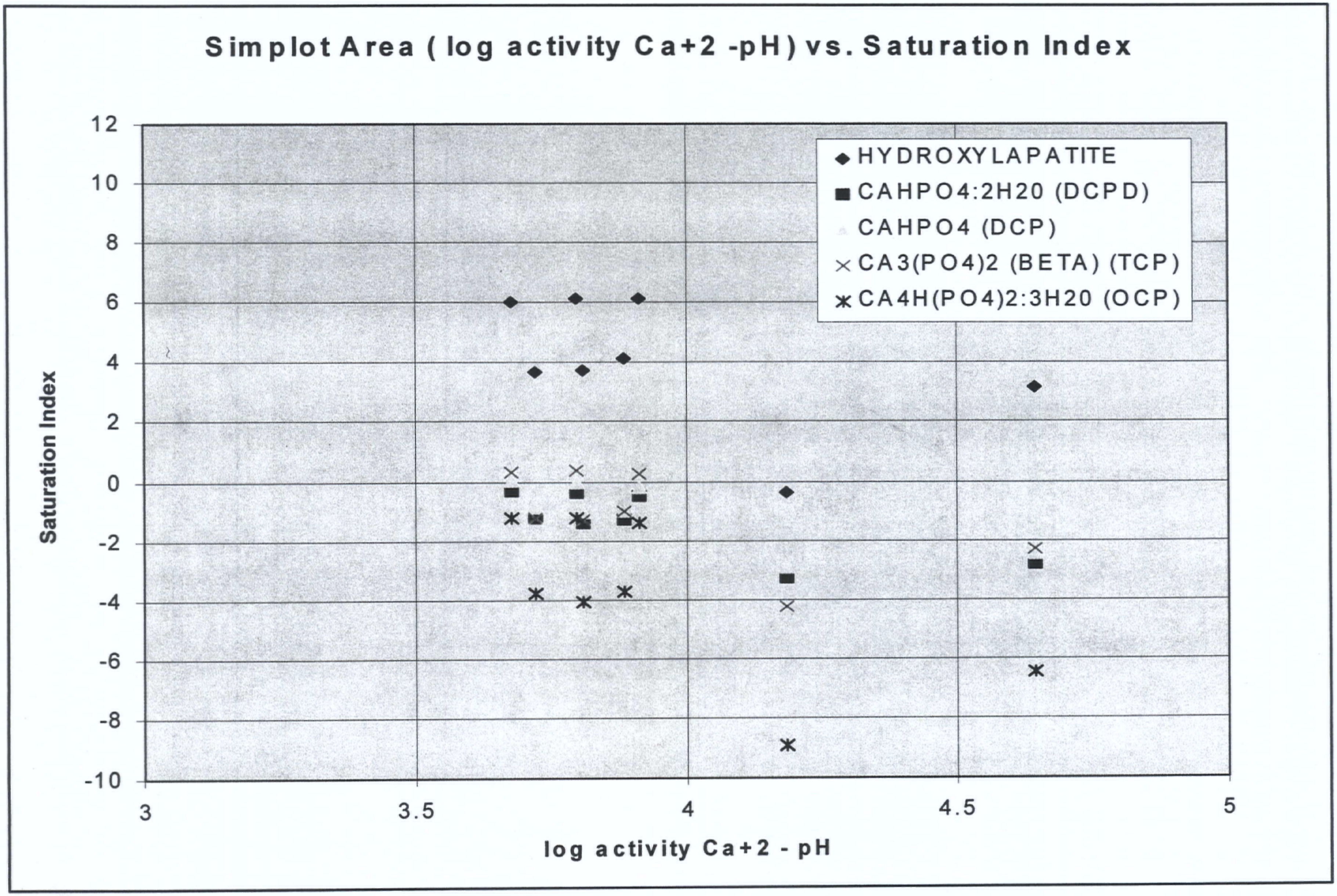


Figure 17. Log activity Ca+2 – pH vs. Saturation Index for Selected Minerals for Simplot area wells.

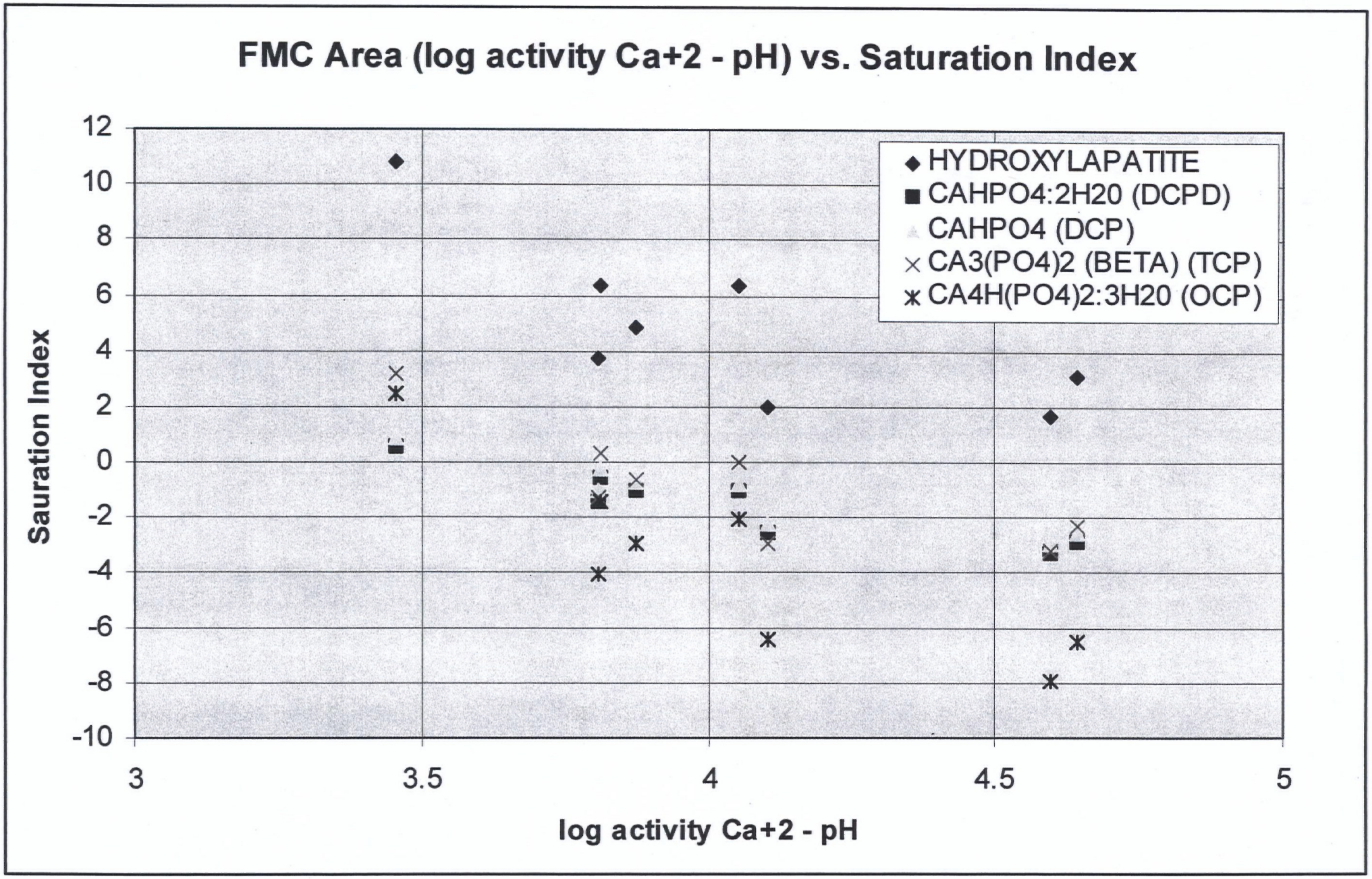


Figure 18. Log activity Ca+2 – pH vs. Saturation Index for Selected Minerals for Astaris area wells.

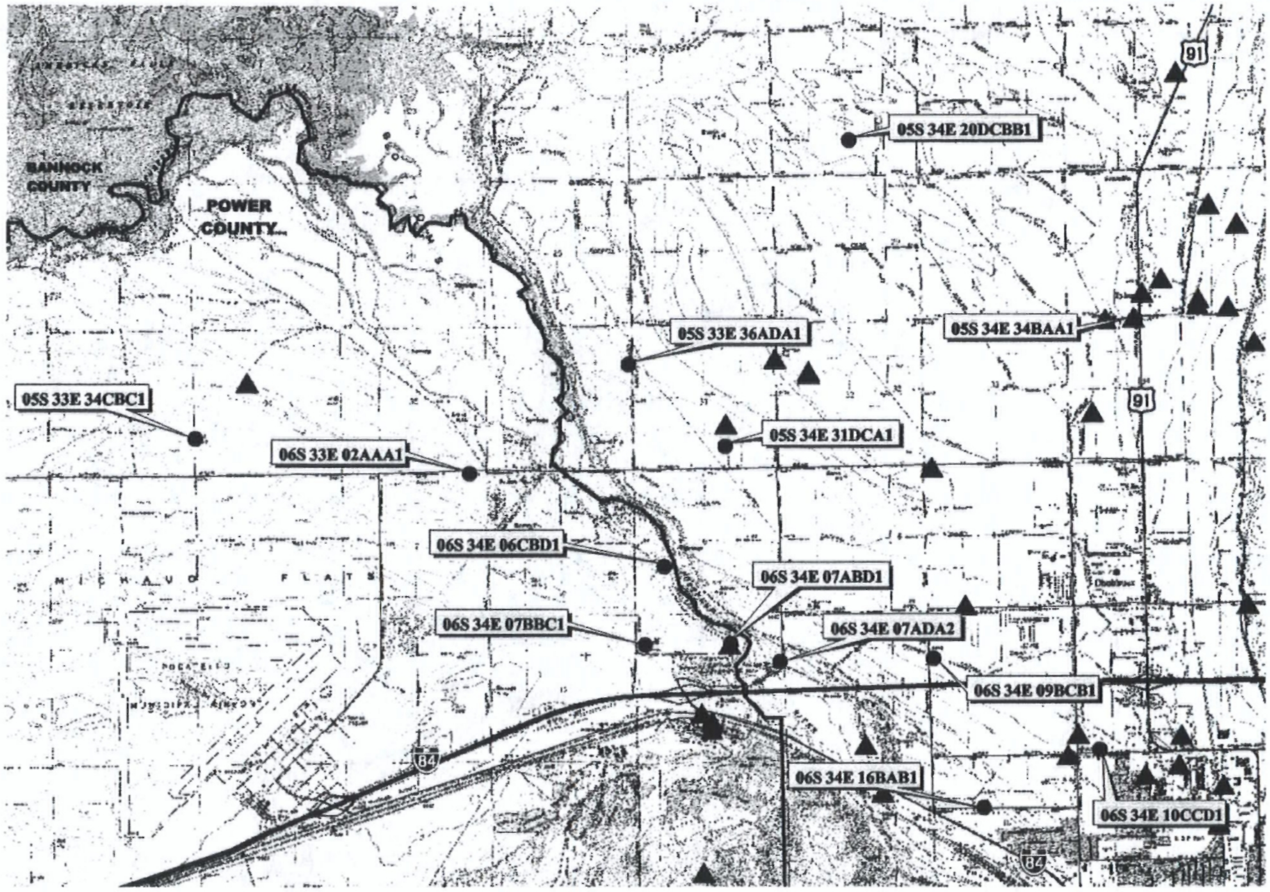


Figure 19. Station ID (Township, Range and Section) for 13 Statewide monitoring wells in the vicinity of the Eastern Michaud Flats area. Triangles show locations of public water supply system (PWS) wells.

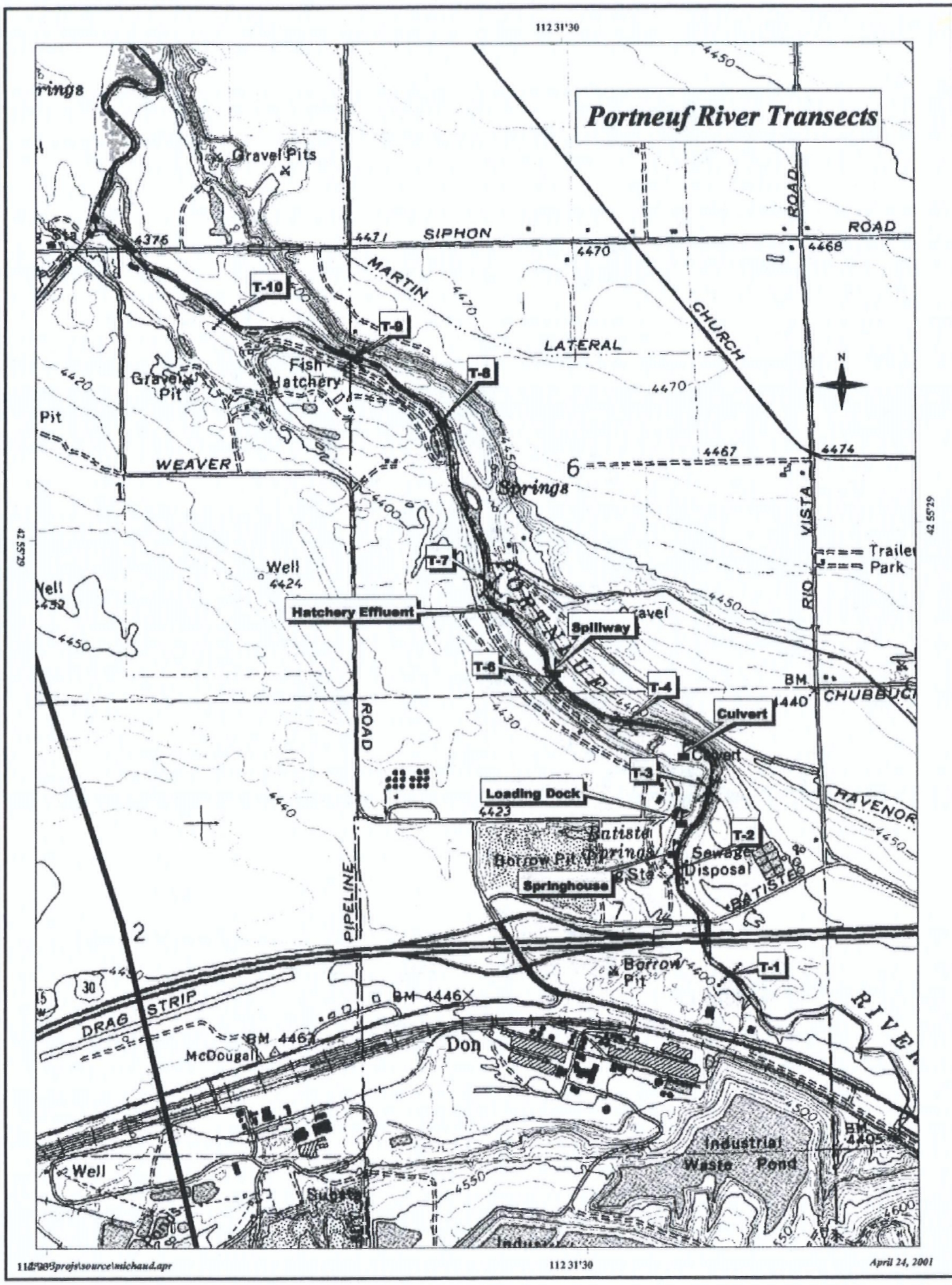
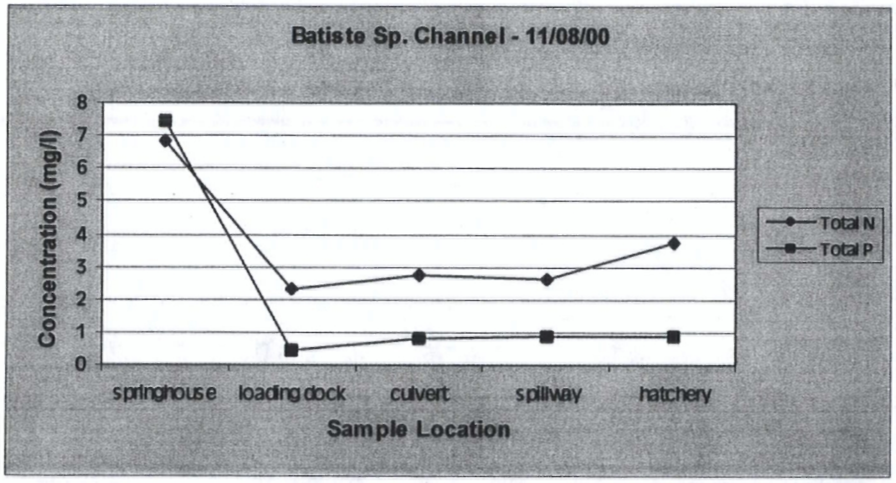
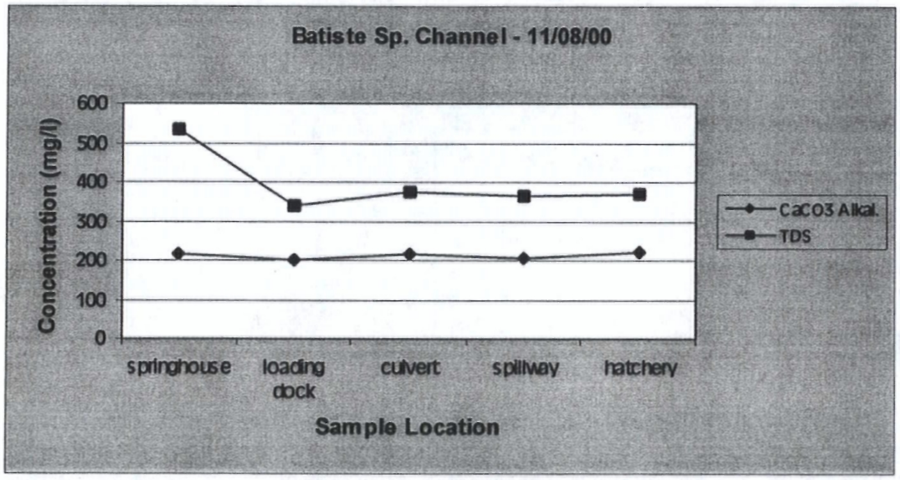


Figure 20. Transect locations sampled along the Portneuf River on September 13 and 14, 2000. Also shown are five Batiste Spring channel locations sampled from May 4, 1995 through December, 7, 2000.





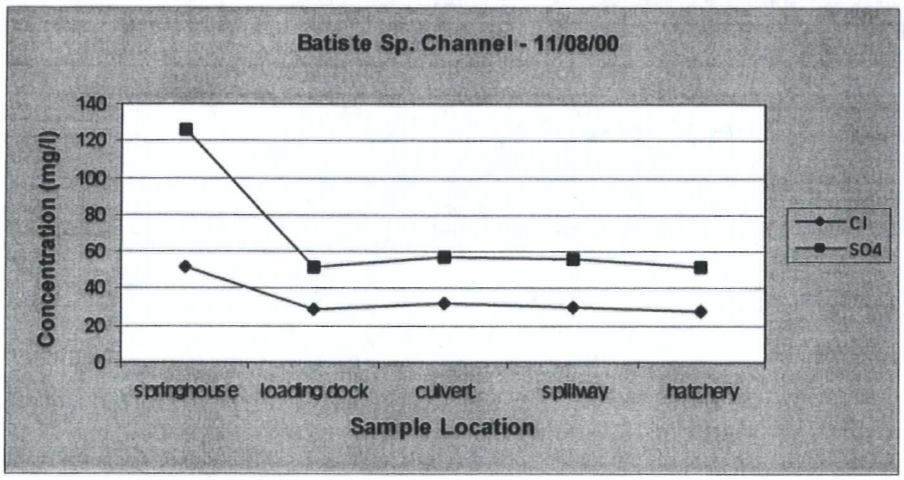
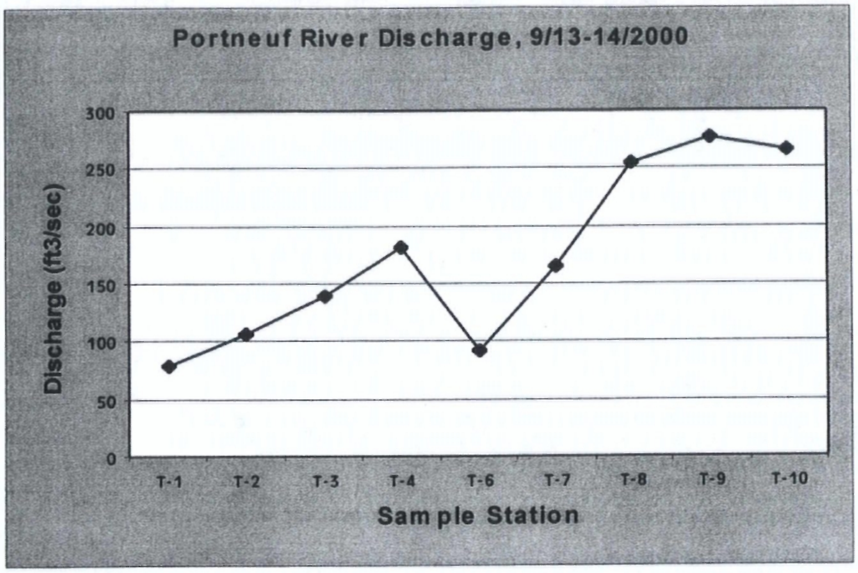
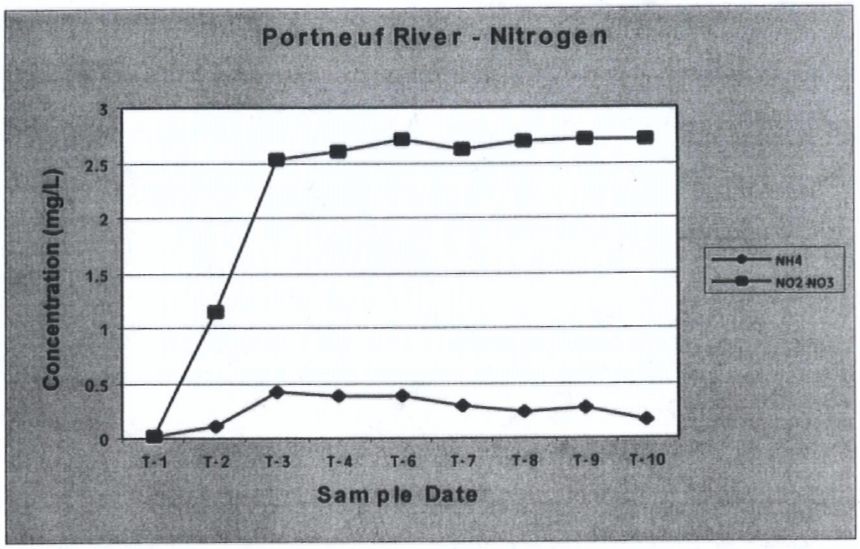


Figure 21. Water quality parameters for five sample locations along Batiste Spring channel, 11/08/00.





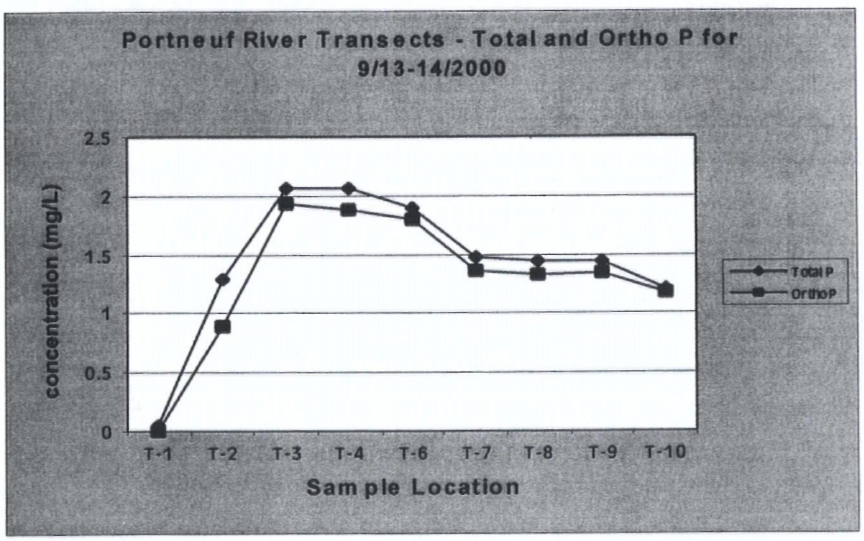
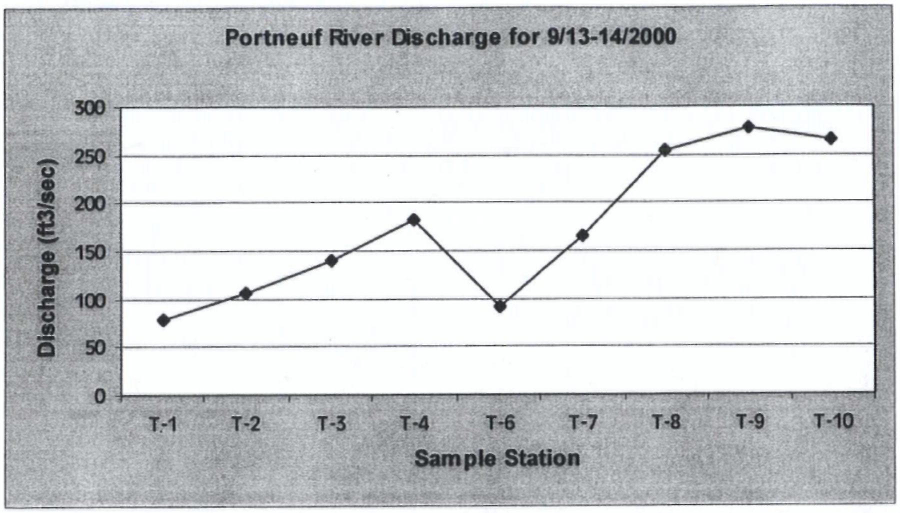
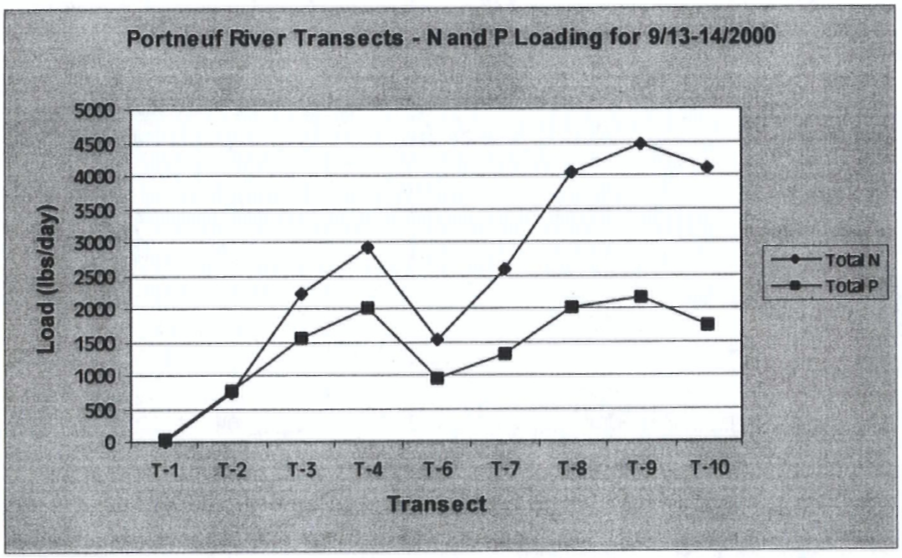


Figure 22. Discharge, total and orthophosphate, ammonia, and nitrite/nitrate concentrations for Portneuf River transects.





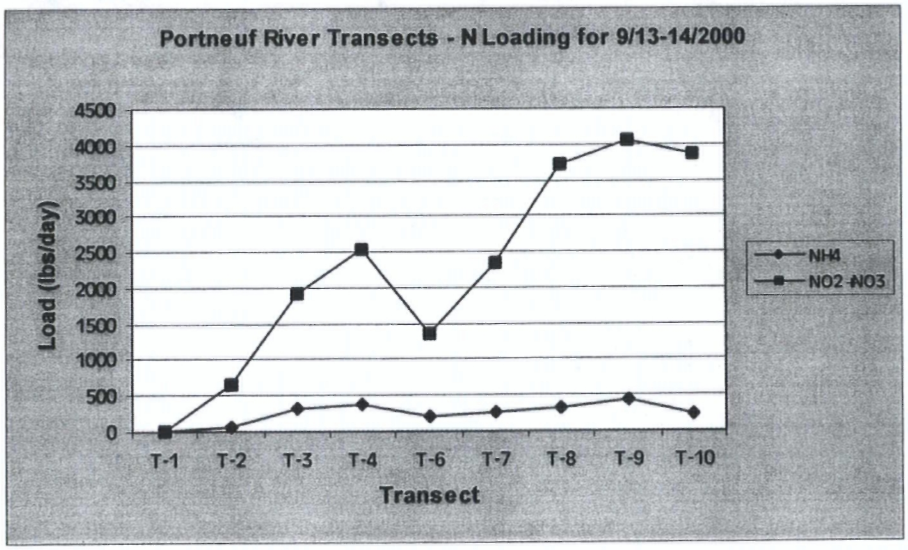


Figure 23. Discharge and loading, in pounds per day, for total and orthophosphate, ammonia, and nitrite/nitrate for Portneuf River transects.

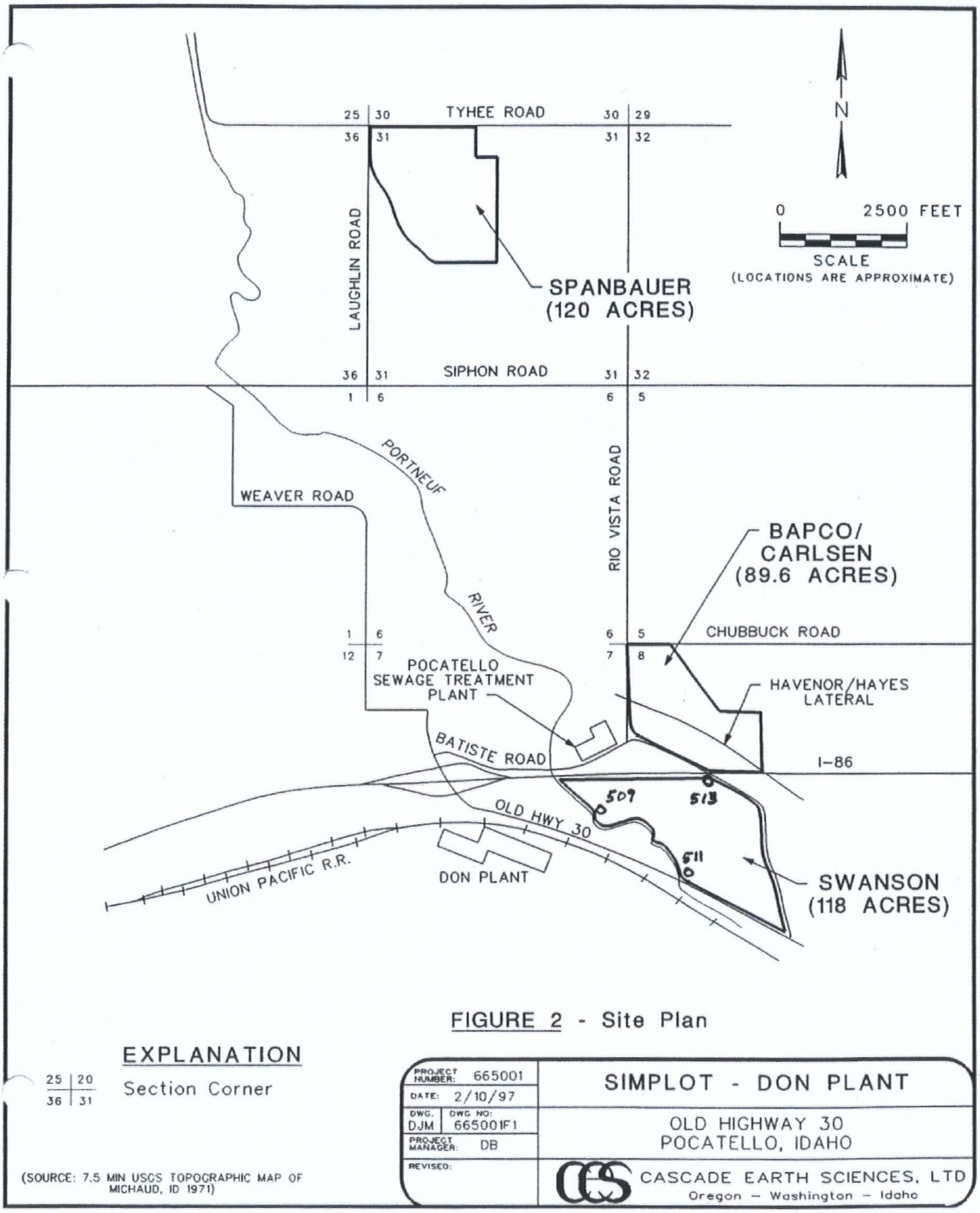


Figure 24. Location of Simplot Don Plant wastewater land application acreage on east side of Portneuf River. Locations for monitoring wells 509, 511 and 513 shown for Swanson acreage. (Adapted from Cascade Earth Sciences, May 20, 1998)

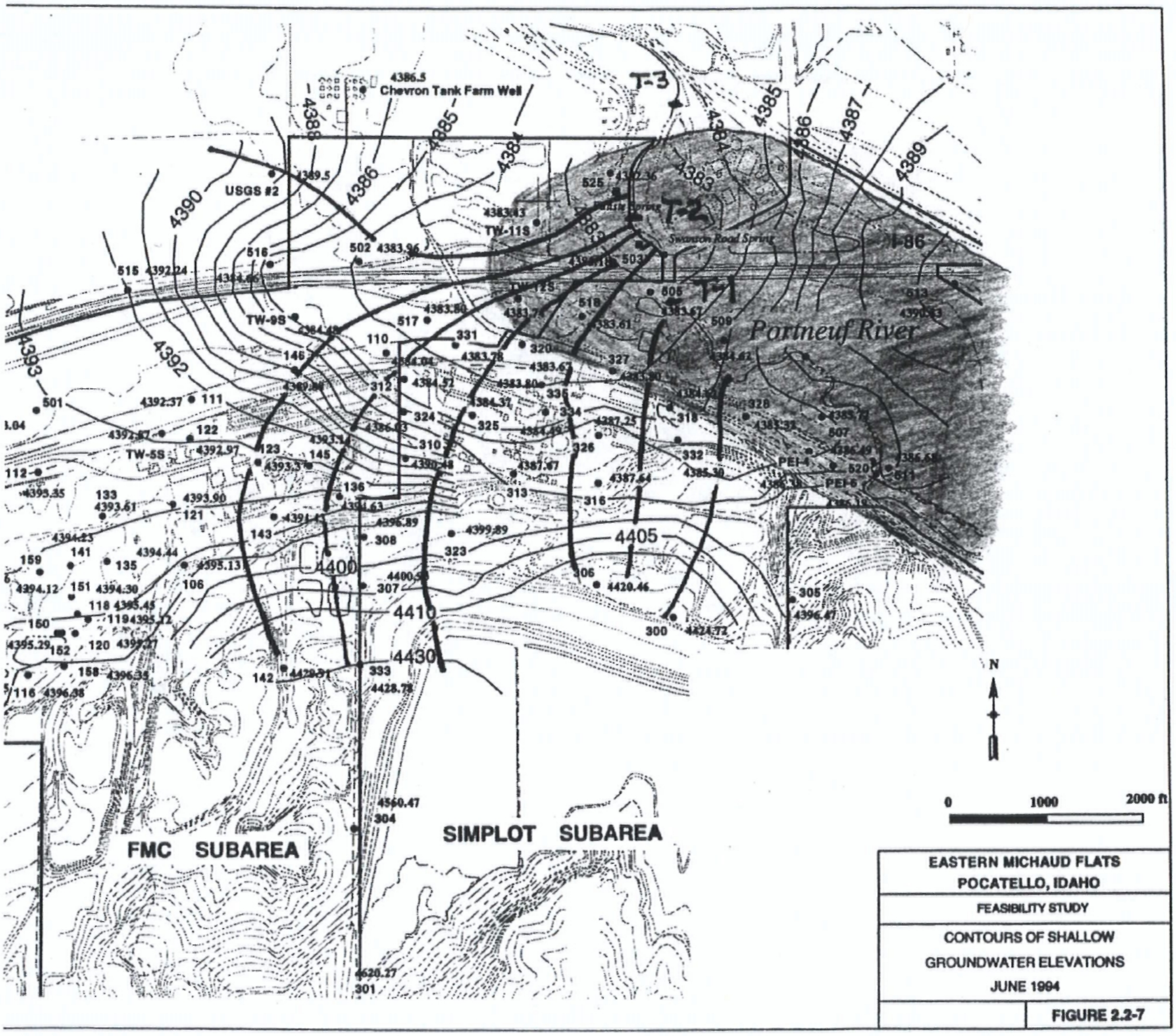


Figure 25. Ground water flow paths used for phosphorous loading calculations. (Figure adapted from Bechtel Environmental Inc., 1994.)